Balancing the Equation of Undergraduate Research: The Importance of Reading, Learning, and Presentation Stability in the Success of STEM Laboratories

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Undergraduate research is an inquiry or investigation by undergraduates that makes an original, intellectual, or creative contribution to their discipline. Research at the undergraduate level has, for many decades, been one of the most prestigious extracurricular activities performed by students, especially for research in the STEM (science, technology, engineering, and mathematics) fields. Undergraduate research gives students the opportunity for a hands-on experience in their field, and many students who join a research lab find that they are closer to discovering their calling as learners and contributors to the world in which they live . The research experience is a valuable tool that helps to find a major and lifestyle that best suits students (Houlden, Raja, Collier, Clark, and Waugh, 2004). The ultimate goal of a research group where faculty, graduate students, and undergraduate students work together is to discover knowledge not previously known, and to then proceed to publish a paper in that field. A published paper with an undergraduate as a contributor is a huge accomplishment in the professional realm, and a student will find themselves already making their mark in STEM fields.

Research is a wonderful opportunity; however, not all undergraduates pursue it. This may be because of how intellectually arduous the process is, or because of how physically demanding a research lab may be. These two aspects—the intellectual compression of knowledge from material outside of classes and physical presentations—are the two main activities that members in research groups focus on. Presentations are an important part of professional development, and they offer undergraduates the chance to receive valuable feedback on their work. They provide public speaking experience and help to deepen individuals' own understanding of their research as they explain their project and respond to questions. The readings of other published papers, other textbooks, and the understandings of other concepts outside of a student's classes is an achievement that must be worked hard for by all members of a research group.

In a study to observe how research affects students, Houlden el al. (2004) expresses:

> The Critical Enquiry elective appears to increase student confidence in their decision to pursue a career as a physician investigator and may encourage some students in selecting this career path. However, students recognize other benefits

> including the development of critical appraisal, information literacy, and critical thinking skills; and the opportunity to select an area of and form contacts for postgraduate training. (p. 661)

It is apparent that experience in a field will expose students to their true liking of their interests, and it will teach students valuable skills needed outside of a university. As a system that aims at advancing general human knowledge in the world, research groups undoubtedly have extra memorization of information and work than a normal academic setting, but what about research groups makes "extra" studying and working actually a "suitable" amount of studying and working so that more students find themselves involved and more papers can be published? Are these two aspects, compression of knowledge through reading and physical presentations, related to how many papers are published annually in a research group?

Literature Review

A community must have a standard for anticipated levels of aptitude in each member because the communicative processes in attaining its goal is based on each member's informative experience, comfort, and involvement in the system (Roozen, 2010; Beaubien, 2008). For the success of undergraduates in their learning, presenting, and contribution to published papers, it is important for all members to see that "disciplinary writing expertise is informed not just by extradisciplinary texts and discourses but also by the practices involved in their production and use" (Roozen, 2010, p. 346), meaning that, to STEM research labs, the creation of activities is just as important as their development, use, and frequency in the community. For example, new projects are being started in research groups very often, and the manner in which the projects are started (how many members are assigned to work on them, where they are started, and what paperwork must be completed to begin experimentation) is just as important to the success of the group as actually performing the experiments. Undergraduate research labs are constantly changing projects, focus, and members, and the activities that are used to bolster the publishing of papers should be monitored as they also may need changing.

It is important to investigate personal experiences in a community so that specific writings and perceptions can be analyzed that aid in the understanding of how a community should function (Devitt et al., 2003; Kain and Wardle, 2014). Anis Bawarshi, a composition author studying the effects of genres on existing activity systems, states that "[a] community is built on the premise that what we know and do is connected to the language we use" (Devitt et al., 2003, p. 549), and that "whether examining legal, medical, or pedagogical genres, genre study gives us specific access to the sites of language use that make up communities, in all their complexity" (p. 549). The collection of writings and experiences from members of the community will show not only how the system is accomplishing their goals but also how those motives are affecting the members personally. Kain and Wardle (2014) show the importance of each individual member of a community with the statement:

> As people participating in activity systems learn, and as new people join the activity, they refine their tools and create new ones… [and] as people change the tools they use, or the ways they use existing tools, changes ripple through their activity systems… Social needs many change and activity systems may need to refine their outcomes or goals to meet those needs." (p. 278)

It is clear that a community such as a research group should be flexible in its function, creating significance in setting a standard for the two main aspects that influence annual published papers. In other words, being overwhelmed or underwhelmed with the amount of learning and presenting in a research group can happen, and a flexible community should be able to alter its divisions of functionality to fit the best path leading to its goal.

What I intend to do with my research is to provide evidence that shows a correlation between extensiveness of learning material and physical presentations in a research laboratory. In order to do this, I gathered evidence from a researcher with experience in laboratories and analyzed their usage as well as the pace of their creation.

Methods

A STEM research group at a university focuses on the analysis of material in science in order to reach new conclusions, effectively furthering human knowledge in a STEM field. Usually, research groups contain (in descending order of experience and overseeing influence in the lab) professors, graduate students, staff, and undergraduate students. My research focuses exclusively on the undergraduates, and data collected is to determine how reading and presenting affects the outcome of annual published papers.

I have had the opportunity to focus on a researcher named Roger who is majoring in the engineering field but has been a member of research groups in different STEM disciplines. Roger is an undergraduate student at the University of Florida and he has been in three research groups throughout his undergraduate experience, one of which he is currently in. He is majoring in Biological Engineering, and has found these groups extremely useful in his pursuit to find his career interest. A focus on his experience is important to provide evidence, in the form of various genres, which shows how a research group reaches its goal through presentations and readings.

The first research group he was involved in was a chemical engineering research lab during his freshman year. The second research group he was a part of was a chemistry research lab where he stayed for two years, and the third research group is in a biomedical engineering lab where he is currently involved. Since Roger does not attend school close to me, interviews were conducted either through a Skype call or messaging on the Facebook social networking site. However, I was able to meet with him to collect two black notebooks that he kept while he was in two of the three research groups. All other forms of writing from all three research groups were sent to me electronically.

The data collected from Roger consists of notebooks, write-ups, self-evaluations, graphs, raw data, and PowerPoints used for presentations. As stated before, the goal of a STEM research group is to discover knowledge in science and to publish a paper. The two main activities that seem to affect the frequency of published papers annually are the compression of knowledge and physical presentations. My research will focus wholly on these two activities. In the case of my research, the compression of knowledge is the pressure to learn an extensive amount of material at a faster pace than an ordinary academic class, and presentations are the physical, verbal, and communicative skills that must be present in each researcher to contribute in a research group. The three research groups Roger was involved in can be summarized in this table:

Discipline of Research Group	Number of Members	Involvement Length	Meeting Frequency	Presentation Frequency	Hours of Reading Per week	Papers Published Annually
Chemical Engineering	15 people	1 semester, Freshman year	Once a week	None	1-2 hours	About 20 papers
Chemistry	14 people	2 years, Freshman to Junior year	3-4 times a week	1-2 times a month	6 hours	1 paper
Biomedical Engineering	14 people	Currently	Once a week	Once a semester	6 hours	10 so far this year

Table 1: Roger's Research Groups

Before a conclusion can be made on how readings and presentations affect accomplishing the goal of publishing papers, let us examine the personal experience of Roger and his writings. For the reason of information availability, I will be comparing mainly the current biomedical engineering lab to the chemistry lab.

Compression of Knowledge and Form Comparison

Learning new material, especially as an undergraduate student, is key to being able to contribute to a lab. Having so much to learn in such little time, the knowledge must be compressed by efficient means. Evidence of this packaging of knowledge is clear in Roger's notebooks, write-ups, a self-evaluation, and communication methods. These forms of writing, resembling the knowledge that Roger obtained, will be compared throughout each research group. In the form comparison, I present each form of writing in the research labs, compare their composition, and analyze Roger's personal experiences when he created them.

Form One: Black Notebook

Roger has written in and completed two "black books": one he kept while in the chemistry research group, and one that he currently uses in the biomedical engineering group.
Pictures of Roger's black book kept in the Biomedical laboratory (to the left) and Chemistry laboratory (to the right) are shown below:

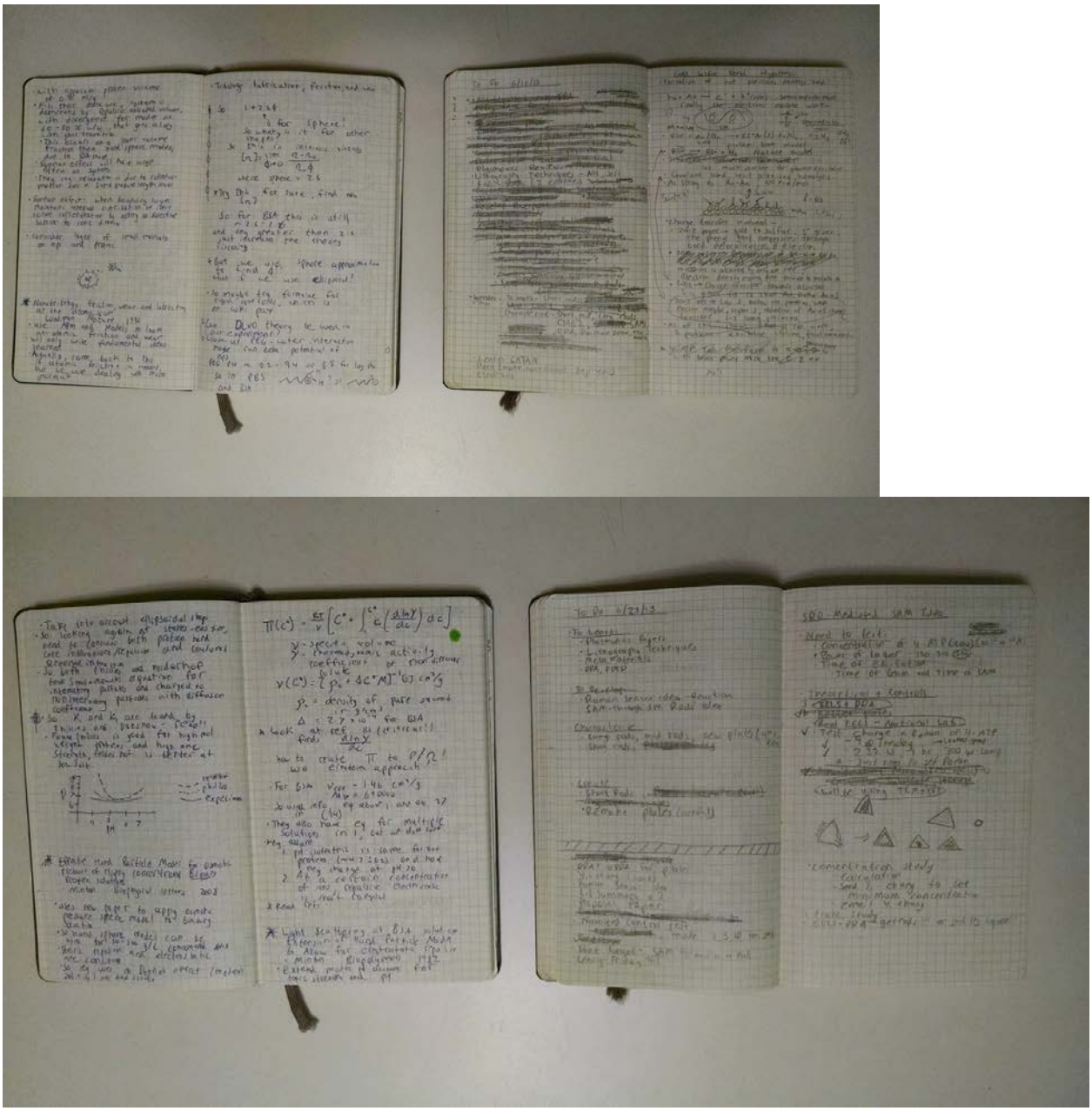

Figure 1: Roger's Black Books

When taking a look at the books, it is obvious that the writing in the book kept for the chemistry group was disordered compared to the current black book. When asked why this may be the case, Roger said, "I now put down equations and graphs, as well as the summary of every paper I read that relates to my project. This helps me in getting all the data I need in one book, since in my old lab I never did this and forgot a lot of things I needed." Roger also noted, "The chemistry group was very stressful; I had to read so much per week and so my notes were not as organized and thorough as they are now. The more I had to read, the harder it was for me to make sense of my own note taking when I looked back into the notebook for a review." This could mean that Roger experienced an overload of knowledge in a short time period, negatively impacting his involvement in a research group.

Bawarshi explains that "an understanding acknowledges the materiality of language, but does not necessarily give us access and insight into the complex motives, relations, commitments, and consequences that accompany the use of language to get things done in specific situation" (Devitt et al., 2003, p. 549). This points out that Roger's personal writings and expressions of involvement may reflect how the lab functions when all members come together, and can demonstrate the errors in its methods of compressing knowledge.

Roger's contribution is important to the success of the research group despite his background in each discipline, but he had the pressure to not only find time for reading many papers a week but means of remembering the material from papers at a fast pace. To do this, he wrote spontaneous ideas, summaries of papers, and planned in these black notebooks.

Perhaps the chemistry research group simply calls for members that have a more developed background in chemistry, whereas the bioengineering research group may be able to have a larger variety of students function comfortably in the lab. However, the required reading in both groups was about six hours per week, and Roger feels that the free time to be able to take notes in the best way possible is much more now than it was in the chemistry lab. The prevalent reason for this is in the intensity of the forms of writing discussed next.

Form Two: Write-ups

Write-ups are a common piece of writing for undergraduates, and they are recordings of information mostly in the form of raw data to be given to a graduate student or professor who is actually writing a paper. For example, a graduate student in Roger's chemistry lab asked him to create a write-up on how to synthesize a nanoparticle, where she then analyzed the information he collected and determined whether or not the data was useful in progressing the paper. Roger may also create a write-up that summarizes group activities or meetings that occurred earlier in the week.

Undergraduate students are most useful for activities like this. Roger says:

In my old group, [the professor] didn't need actual write ups of my data and more, just summaries of group meetings. In this new one, I write up all my data and questions and analysis and [the professor] writes in what I need to do. It's a much better system.

Roger's usage of time in creating a write-up now is focused in on his findings for the specific project he is working on, rather than summarizing activities that may not directly forward the progression of publishing a particular paper. Because Roger had to take time to make a write-up on group meetings (which took up to two hours at a time), he had to sacrifice the time needed for reading papers and learning about the project of interest which he recorded in his black notebooks.

Advancing knowledge in fields that require a technique of learning in a methodological manner is difficult and a strong focus is required. Greg Beaubien (2008), on the expression that fewer, tighter, actions in writing yields better results, expresses the metaphor:

> Imagine a blank white wall. The word 'freedom' is painted in big black letters across the center. As a piece of writing, this single word in a punch. Now, imagine the same will cluttered with dozens of other words. The impact is lost. (p. 21).

Keeping a focus on a student's project through all channels in this community will only help the group reach its goal of publishing a paper.

Kain and Wardle's (2014) statement that "social needs many change and activity systems may need to refine their outcomes or goals to meet those needs" (p. 278) demonstrates that it is clear a community such as a research group should be flexible in its function. Regressing away from the goal of establishing new discoveries should be recognized and altered to better the chances of reaching that goal. In order to increase this chance, write-ups should focus on the student's project and personal questions rather than focusing on peripheral information, which then affects their personal involvement in the research group.

Form Three: Self-Evaluation

The chemistry group was the only group that required Roger to complete a self-evaluation. In this self-evaluation, Roger was asked what his anticipated achievements are for the lab and a personal background. Roger, on its effectiveness, states:

> I believe [the self-evaluation] wasn't necessary. I wanted to work on research, and I knew what work and how much more work I should have done each semester. Only certain communications and assignments are needed. However, it did help me realize that I didn't want to continue with research in a chemistry group.

The ability to rule out excessive activity in a community so technical shows members that the main goal of the group is to advance knowledge, and perhaps not to examine each member's personal background and information that will not ultimately drive the group to its objective.

Of course, each member of the group should feel valued as an individual but that can ultimately occur in the acceptance of their data and individual thought toward the project. The sense that a researcher is valued and that their understanding of the project is going as efficiently as possible can happen through all channels of communication without leaving the substance of the project. Leaving the topic of their research in the form of required assignments may have a negative impact on the research group as a whole, considering Roger decided against a research lab in the chemistry department altogether. However, in his current lab, the only requirements are that he shows up to meetings, writes for his graduate students, and keeps in touch with his professor often. The chemistry group, in the course of four years, published one paper. The biomedical engineering lab, so far this semester, has published ten.

Individuals in research labs don't have to regress away from the paper at stake in order to assure the involvement of members. It seems as if more time spent on each individual project yields better results not only in the quality of contribution from researchers, but the number of research papers published, too.

The ultimate function of each activity in a research lab should be analyzed in various contexts, as some forms of its occurrences may actually hinder the attainability of its goals. Roozen (2010) believes that "data collection needs to address a wide range of participants' semiotic performances, not just activities that involve the production of seemingly similar kinds of texts" (p. 347), which adds meaning in the chemistry group member's consideration of how assignments that are aside of each project such as the self-evaluation really contributes to the advancement of knowledge in science.

Meetings, Physical Presentations, and Form Comparison

Involvement is key in research, and as Kain and Wardle (2014) state, "We differentiate types of activities by the specific knowledge, tools, and repertoires of tasks that people use to achieve particular outcomes" (p. 275). As stated before, presentations provide public speaking experience and help to deepen individuals' own understanding of their research as they explain their project and respond to questions. If presentations did not occur, the conveying of ideas and projects would be difficult for members to eventually do. Therefore, research groups attempt to have the group contributing to its success at a constant rate. This includes having them do presentations and to speak to other group members often. Therefore, I will now examine the effects of communication and physical presentations separately.

Roger claims that the current biomedical engineering group he is in communicates best because he meets with members of a higher position than him regularly. He said, "I talk to group members a lot, everyone is friendly, and I meet more and communicate my ideas more with my professor." A notable difference in his current group compared to the others is that he meets with the professor more. This way, he is speaking to someone that can determine whether or not his thoughts and work are furthering the group's efforts.

In the Chemistry group, he was required to meet with only graduate and undergraduate students quite frequently, and he said he didn't meet with the professor often at all. Roger said, "I maybe met with the chemistry professor once every three months. The only time he looked at the work I was doing was during group meetings, which wasn't helpful because it wasn't one-on-one." Evidently, the chemistry research group, according to Roger, met too often in unsuitable ways. As demonstrated in the chart given at the beginning of this paper, the chemistry group met with each other 3-4 times a week, while both the chemical engineering and biomedical engineering group met only once a week. Undergraduates and graduates meeting to discuss matters unrelated to the direct project doesn't help the research group reach the goal of publishing papers, and neither does scarcely meeting with the facilitator of the entire lab.

Research is an involved and continuous process. A research group needs to attend to the development of their knowledge through physically meeting with and talking to members of higher position, not with those of essentially the same standing, to ensure the development of each graduate student's project. Unmistakably, the frequency of meetings in a STEM research group not only has to occur at the right pace, but must contain the best quality in each member's experience. This may reveal that in order to have an effective research group, one must constantly be talking to others so that they can think critically about an idea and examine different viewpoints. Collaborating with others that are more knowledgeable on a subject is the most influential way to expand an understanding of science in a setting that isn't a classroom.

Learning can occur by one's self, but the activation of this knowledge that contributes to discoveries in science happens with collaboration. Physical presences by Roger with other members of the groups occurred in presentations where he spoke to the group exclusively and meetings where all group members spoke to each other. I now compare the two forms of physical appearances made by Roger to analyze the effects of them throughout the different labs.

Form One: Presentations to the Group

When Roger presented in each group, he created PowerPoints, graphs, and raw data, as well as relevant information to the context. In the chemistry group, he presented in group meetings and literature reviews, however he did not present at every meeting. At group meetings in the chemistry group, presentations were a brief update on what he was doing in the project. This was good because the professor was there; however, he only presented twice the entire semester and the professor's feedback was vague and quick as there were other members in line to present their work as well. Roger said, "If I were to present one-on-one with the professor, the feedback would have been more valuable to me." In literature reviews, Roger presented summaries of papers that were not necessarily relevant to his project. The bulk of his presentations in this group came from literature reviews, and he stated, "These presentations didn't help me with my project but they made me a better presenter."

In his current biomedical engineering group, he presents in the only form of gathering: group meetings. He presents twice a semester here. This way, each group meeting can focus on only one or two presenters, enabling not only the professor but every group member to assist them. Presentations in his current group do not serve as assignments—they serve as helpful activities that will enhance the pace and quality of each research project.

Roozen (2010) states the following:

> The work we need to invite learners to do seems less about employing extradisciplinary practices only with an eye toward replacing them at the first opportunity and more about encouraging learners to view them as flexible resources for creating, maintaining, coordinating, extending, altering, and perhaps even productively disrupting networks that provide access to disciplinary expertise." (p.348)

This highlights the emphasis of presentations on relevant materials that enhance the quality of a specific project. This seems to be related to how many papers are published each year, and we see here that there is a higher productivity level within STEM research groups that act with quality, not quantity.

Form Two: Meetings

Each research group had its own unique forms of meetings that Roger was required to attend. In the chemistry group, there were three types of meetings. The first was a standard group meeting, which was a brief update on what each member was working on. The second was a subgroup meeting, where graduate and undergraduate students spoke about their work without the professor. The third was a literature review, where members were to talk about primary research they have analyzed. This primary research did not have to do with each member's project, but it did have to do with chemistry in itself.

The biomedical engineering research lab calls for a lot less meeting time and a lot more discussing each individual's project. They meet once a week for about an hour. However, Roger meets with his professor one-on-one up to once a week if he needs by making appointments. The chemistry group's professor did not make himself available for individual meetings, leaving Roger's only time with the professor to be in group meetings. Roger believes that the meetings in the chemistry group were excessive and the time he had to actually work on his project and learn the required material to advance it had diminished with the more time needed to put together presentations and analyze literature. He now feels that he interacts with the facilitator of the lab often enough to keep his thoughts focused on the project. Roger said:

> Meetings are important, particularly group meetings and one-on-one with the professor. For the group meetings, you can practice presenting your findings to a group as well as get criticism and ideas from the group. It can also help the professor critique several people at once. One-on-one meetings are the best, since you can talk directly to the professor about your project and what route to go with it and data analysis and many other things.

The latter function of individual meetings wasn't accessible to Roger in the chemistry group, leaving an area needed to direct his research vacant.

Ultimately, the most valuable act a research member can do is formulate ideas that can potentially broaden the world's knowledge of science. In order to do this, members must pool and compare resources, as well as physically present their ideas and collaborate with others. This keeps the mind sharp and current, enabling any member to ask quality questions that lead to untested discoveries.

Discussion

Devitt, Bawarshi, and Reiff (2003) state that "the communal agendas of those who create genres may conflict with the interests of those who use them" (p. 549), and I found that if an undergraduate creates a genre that is not related to their work directly, the work output from perhaps all members is subpar. These authors also state that "to understand more fully these genres is to understand more fully how the generic materialities are their uses-in-contexts, with serious effects on people's lives" (p. 549) and I can see in the need for communication between members of all expertise that the writing and reading that takes place in research needs to be analyzed carefully in order for it to translate smoothly. After all, research in science fields is meant to positively affect people's lives.

My research shows that academic settings driven by different scientific forces all may have the same source for their genres, such as a PowerPoint, a note-taking guide, or write-up, but they all function with a different weight on the community. Roozen (2010) states that "data collection

needs to focus on illuminating the practices and processes of textual invention that obtain in those activities" (p. 347), and I find in this statement how critical the textual invention of writing can be in academic communities. The collection and analysis of data should be done with means of understanding their usage but also the circumstances and pressure in which they were created under. Devitt et al. (2003) writes that "analyzing genres within their lived contexts reveals to students, teachers, and researchers the material strength of those communities and their power over members and nonmembers alike" (p. 549), but I think that these lived textualities have just as much weight on the community in their creation as their use.

When discussing how communities function with writing and rhetoric, I feel there needs to be more an emphasis on the creation of the text. Observing how they fit in with the community after they are created is an important part of altering communities to best serve their purpose, but I feel that the state of the members and the community at the point of creation is a part of the alteration process that deserves just as much attention. Their creation then affects how each member functions in the community. For instance, if Roger had not needed to complete the self-evaluation, he may have had more time to focus on reading primary literature or performing experiments.

Conclusion

I have found that the content required to be learned by an undergraduate in a research group should be directly correlated with the member's current project, not correlated with other projects or excessive assignments. It is evident that there can be cases of overload in group work that may not have to be a part of the system. Roger experienced an overflow in this area, specifically in the chemistry research group. He was reading material not necessarily dire to the project he was working on with his graduate student, and he presented with the anxiety of analyzing papers with content he was unfamiliar with.

Reading and writing are just as rigorous of activities as training for a sport; there needs to be prior practice to achieve an ultimate goal, and overworking the body intellectually can be just as damaging to the activity system as breaking a knee is for a sports team. Of course, learning must never stop and should always be in motion through reading, presentations, and meetings, but a group member's goal is to publish a paper and it should be the main factor in each lab activity.

There are ongoing questions principally about the characteristics of students willing to take on more than their academics. The treatment of undergraduate researchers should be based on, of course, the load of reading and presentations, but future research should be done discussing the type of students that are generally apart of a research group, as well as the discipline or specific topic of STEM research that is happening. This will open research labs to more varieties of students, increasing the amount of student involvement in science, successfully furthering our understanding of STEM fields at an increased pace.

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