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Collaborative Learning in an Undergraduate Life-Sciences Living-Learning Program: Case Studies at Multiple Planes of Analysis

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The authors report on a living-learning program (LLP) designed to transform life sciences education. One goal of the LLP is to engage students in collaborative learning. Little research describes interactions and experiences within an LLP that encourage collaborative learning. This qualitative ethnographic study explores the following questions: What are some of the ways in which collaborative learning occurs in an LLP? and What factors influence how, when, and to what extent collaborative learning occurs in an LLP? The authors aim to identify ways to promote collaborative learning in an LLP and provide insight for others wishing to construct LLPs with similar goals.

Research Problem

Undergraduate life sciences education is typically structured so that students complete free-standing courses in which they learn the content through lecture and textbook readings. This style of instruction is not consistent with the learning of practices of science or medicine, which value collaborative work (Wood, 2009). Recent reports, including *Vision and*

Change in Undergraduate Biology Education: A Call to Action (V&C) (AAAS, 2011), have focused on improving undergraduate life sciences education by cultivating students' biological literacy and practicing student-centered learning. We report on the Integrated Life Sciences living-learning program (ILS LLP) at the University of Maryland, designed to transform life sciences education as suggested by V&C (Cooke, Quimby, Horvath, Jardine, & Levin, 2016). In this program, students live together on the same floor of one dormitory, take a core set of classes together, and participate in group excursions and community service.

One of the main goals of the ILS LLP is to engage students in collaborative learning, both in the classroom and as a community. There is ample research on the benefits of social interaction and collaborative learning in undergraduate classrooms, especially in STEM fields (for instance, Springer, Stanne, & Donovan, 1999). Research also documents affordances of living-learning communities (for instance, Inkelas & Soldner, 2011), including in STEM education (Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). However, there is little research describing group interactions, individual experiences, or community roles and influences within an LLP that encourages collaborative learning. It is important to understand how students approach collaborative learning within the context of a living-learning program and the diversity of factors that may influence their participation. In order to better understand how we can promote collaborative learning in an LLP and provide insight for others wishing to construct or modify similar programs, we seek to address the following research questions:

- What are some of the ways in which collaborative learning occurs in an LLP?
- What factors influence how, when, and to what extent collaborative learning occurs in an LLP?

Collaborative Learning and Living-Learning Communities

We define "collaborative learning" (Dillenbourg, 1999) as any "situation in which two or more people learn or attempt to learn something together" (p. 1), because this definition is broad enough to address the various ways group learning can occur in an LLP. We agree with Panitz (1999) when he writes, "collaborative learning is a personal philosophy, not just a classroom technique" (p. 3), highlighting that collaborative learn-

ing involves people, with personal beliefs and expectations, in interaction with each other. In distinguishing cooperative learning from collaborative learning, we define cooperative learning as a structured, teacher-facilitated classroom activity that is focused on the products of working together. Collaborative learning, on the other hand, is an unstructured, student-centered means for working through ideas. Aspects of cooperative learning may be present in collaborative settings; however, they are still inherently different. The study of collaborative learning focuses on the process of working together, often using qualitative approaches and analyzing student talk (Panitz, 1999).

Pedagogical practices that promote meaningful collaboration among students can make significant contributions to students' achievement (Astin, 1993). Collaborative learning is associated with gains in academic and career self-perceptions. Students gain in confidence and competence as they experience their own accomplishments (Pajares, 1996). Students also learn from observing other students' accomplishments as they work together (Schunk, 1992).

There is evidence that collaborative learning is effective in undergraduate STEM courses. Springer et al. (1999) conducted a meta-analysis of small-group learning in STEM, focusing on undergraduates in classroom or program settings. The results demonstrated that small-group learning has positive effects on academic achievement, retention in STEM disciplines, and attitudes toward STEM. The study reported large effects on achievement of underrepresented groups and learning attitudes of women. The next step in research in this field is building a stronger link between theory and practice.

The ILS LLP moves beyond creating collaborative learning opportunities in the classroom to creating a living-learning community that promotes collaborative learning outside of the classroom. Tinto (1997) highlights the importance of "classrooms as communities," placing collaborative learning at the core of the academic and social experiences of students. According to Tinto (2003), when participating in learning communities, students form self-supporting groups that extend beyond the classroom. The benefits of LLPs for students, including increased academic and social engagement and increased persistence throughout college, are well documented in the literature (Knight, 2003; Rice & Lightsey, 2001; Zhao & Kuh, 2004). LLPs cultivate a sense of community and belonging, providing students with social support and networking, academic support, leadership skills, and multicultural experiences (Spainierman et al., 2013). Zhao and Kuh (2004) demonstrate there are statistically significant relationships between participating in learning communities and student academic

performance, collaborative learning, interaction with faculty members, and overall satisfaction with the college experience. LLPs facilitate the transition and retention of new students, especially at large institutions (Shapiro & Levine, 1999). Recent research also demonstrates that LLPs improve the success and experiences of STEM students overall (Inkelas, 2008; Soldner et al., 2012).

The expectations that students bring to LLPs may influence the outcomes of their living-learning experience (Wawrzynski & Jessup-Anger, 2010). Wawrzynski and Jessup-Anger (2010) examined students' expectations for their college experience upon entering the living-learning environment and how these expectations, along with their living environment, influenced outcomes. Their findings confirm the influence of non-cognitive variables, such as students' expectations, on student outcomes. For example, students who, before beginning in the program, claimed that they expected to have out-of-class conversations with faculty were much more likely to engage in student-faculty interactions when actually within the living learning environment. We also know that students' epistemological expectations, their expectations about knowledge and learning in science, can influence how they engage in science learning (Redish, Saul, & Steinberg, 1998), and retention in the STEM pipeline (Danielak, Gupta, & Elby, 2014).

In summary, collaborative learning results in higher learning gains, promotes metacognition, helps students develop analytical skills, and promotes positive attitudes about STEM (Astin, 1993; Pajares, 1996; Schunk, 1992; Springer et al., 1999). Participation in learning communities can also positively impact students in many ways. Students who participate in learning communities demonstrate greater academic performance, satisfaction with the college experience, and engagement in extracurricular activities (Knight, 2003; Rice & Lightsey, 2001; Zhao & Kuh, 2004). However, these and other studies on collaborative learning and LLPs focus mostly on arguments supported by quantitative findings. There is a need for more qualitative ethnographic research to provide "thick description" (Geertz, 1973)—to describe collaborative learning in a way that uncovers the interpersonal interactions, the individual expectations, and the norms and practices of a community that seeks to support collaboration. In the sections below, we discuss our analytical framework and ethnographic methods for describing productive collaborative learning and exploring the diversity of individual and community influences that affect how and when it occurs.

Analytical Framework: Collaborative Learning Through Multiple "Planes of Analysis"

We draw on Rogoff's (1995) "planes of analysis" to understand collaborative learning in the ILS LLP from the interpersonal, personal, and community perspectives. Particularly, we take seriously her assertion that sociocultural activity is best understood through these multiple planes of analysis. We view collaborative learning in the ILS LLP through these multiple grains of focus, because this helps us explore the multiple factors influencing collaborative learning. We hypothesize collaborative learning is mediated by multiple factors, including faculty and program staff, teaching assistants, available learning spaces, and student expectations, which previous research suggests influence students' experience in the program (Cooke et al., 2016). We consider these factors through the different planes of analysis to organize and interpret our data and as a lens through which to address our research questions. Analyzing data from different planes of analysis allows for deeper understanding of how individuals fit into the community and how different individuals in the community interact.

We explore the *interpersonal* plane to identify situations in which collaborative learning in the ILS LLP is more or less productive. Following Dillenbourg's (1999) image of collaborative learning as a situation in which people are attempting to learn something together, we view "productive collaborative learning" (PCL) in science to be situations in which students work together to construct explanations and make meaning of science content, inside or outside the classroom. Ultimately, we focus on collaborative learning situations in which students are engaged in scientific "sense-making" rather than simply trying to come up with correct answers to fulfill an assignment or an instructor's expectations (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Not all cases in which students meet together to work on science coursework would fit our expectations of PCL. Some group work may be productive for other purposes, such as developing a sense of familiarity and community in a learning setting; not all group work necessarily involves students working together to make meaning of content. One of our main research goals is to identify and describe what productive collaborative learning might look like *in situ*, in order to help ourselves and others in the field understand how best to support and promote the most productive collaborative learning opportunities.

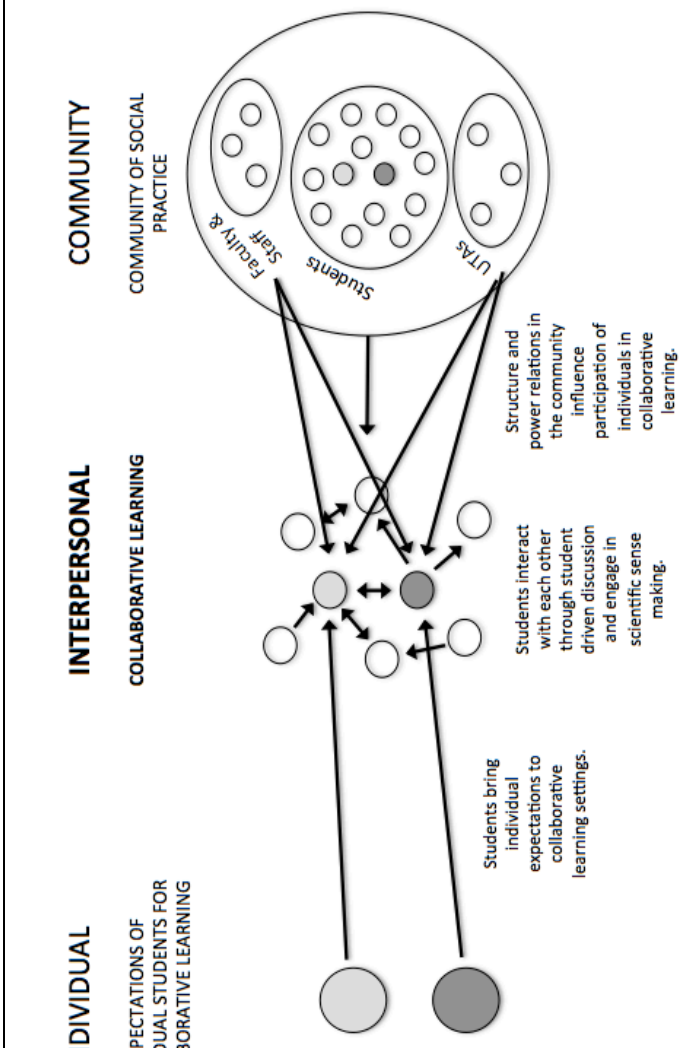
Our exploration of students' expectations at the personal plane follows Hall (2013), who identified three dimensions of expectations that students

bring to undergraduate science classrooms: "epistemological expectations—what students expect to be the nature of the knowledge that they are learning, learning expectations—what it is that they think they should be (or are) doing in order to learn that knowledge, and performance expectations—what it is that they think they should be (or are) doing in order to be successful in a particular course" (p. 1). We narrow our focus to students' *collaborative learning expectations* for this work. That is, what is it that students think they should be (or are) doing in collaborative learning settings in the LLP in order to learn science? While this question overlaps with students' epistemological expectations and performance expectations, it helps us to focus in on students' expectations for collaborative learning throughout the LLP, inside and outside the classroom, and it can be explored by analyzing students' behavior in collaborative learning settings and their reflection on their behavior in interviews. We seek to understand the learning expectations students bring to collaborative learning settings in the ILS LLP and how these expectations may influence their participation in collaborative learning.

In order to explore the ILS LLP from the *community* plane, we consider Lave and Wenger's (1991) theory of situated learning as well as Wenger's (1999) conception of a "community of practice." At this plane of analysis, we consider learners' participation in a community of social practice. According to Lave and Wenger (1991), structure and power relations in the community may encourage and/or inhibit access for individuals to participate in activities of the community, such as collaborative learning. In our case, we explore the effect of the structure and power relations of faculty and staff as well as undergraduate teaching assistants in the community. Additionally, participation in social practices, such as collaborative learning, promotes the formation of student identities in the community. Rather than make any claims that the ILS LLP fits some particular vision of a "community of practice," we use this lens to understand the culture of the community and the ways in which it interacts with individual identities.

As described above, we apply different theoretical traditions when analyzing data at each plane. This allows us to integrate findings from multiple levels and types of qualitative data and various aspects of the ILS LLP. Taken altogether, these different frameworks form our overall framework for exploring collaborative learning at multiple planes of analysis. Figure 1 provides a visual representation of the frameworks applied at each plane and the relationships between them.

Figure 1
Analytical Framework:
Collaborative Learning Through Multiple "Planes of Analysis"



Methods

The Setting: The Integrated Life Sciences Living-Learning Program (ILS LLP)

Academic Program

The ILS LLP integrates two components of the V&C recommendations, cultivating biological literacy and student-centered biology education, throughout its academic program. All students in the program complete four consecutive courses that are taught in classrooms in either the residence hall where the students live or in the community center nearby. The first course, which students take in the first semester of their first year, is an integrated organismal biology course taught by the director of the program. The course emphasizes multidisciplinary perspectives toward the function and diversity of all organisms and incorporates a series of unique small-group, active-engagement exercises (GAEs) (Jardine, Levin, Quimby & Cooke, 2017).

Residential Experience

In order to integrate the charge set forth by V&C to "provide opportunities for faculty and students to work in a collaborative learning community" (AAAS, 2011, p. 21), the ILS LLP strives via the structure and activities of its residential community to be a "community of practice" of collaboration, mutual expectations, and shared vision (Wenger, 1999). All students live in the program's residence hall for their first year and are encouraged to continue living there for their second year. This residential experience provides the structure for creating an engaged and supportive community of students, faculty, and staff by allowing for the ready exchange of ideas, collegiality, and friendship. To facilitate this exchange, student residences, staff and faculty offices, classrooms, workspaces, and recreational spaces are all located in the program's residence hall.

The Approach: Case Studies at Embedded Units of Analysis

Using Rogoff's (1995) planes of analysis as a framework, we adopted ethnographic methods to conduct a case study of collaborative learning in the ILS LLP with embedded units of analysis at the level of the interpersonal, the personal, and the community. The case study approach allows us to explore a real-world phenomenon of interest—students' collaborative learning expectations and participation—while understanding important

contextual conditions—features of the ILS LLP (Yin, 2014). We employ analysis on the interpersonal plane by analyzing discourse from recordings of instances of students participating in collaborative learning behavior. Then, at the personal plane, we focus on the collaborative learning expectations of two students who were present in these interactions. We chose these two students because the recordings from the collaborative learning setting suggested they expected different outcomes from the collaboration, and we wanted to better understand these differences. Finally, we draw from the interpersonal and personal perspectives, as well as additional observations and student responses, in order to create an overall picture of collaborative learning in the LLP from the community perspective.

Ethnographic Method

Ethnographic methods, and particularly participant observation (Peshkin, 1984), allow the researcher to gain a better understanding of the culture of a group—those meanings produced by people that shape and are shaped by the ways they think, feel, and act. In this section, we describe our ethnographic data collection. Data collection methods and participants involved are summarized in Table 1. Subsequently, we describe our analytical methods.

The first author followed a cohort of 54 students enrolled in the LLP from fall 2014 until their completion of the two-year program in spring 2016. She was embedded in all aspects of the ILS LLP, conducting research as a participant observer (Peshkin, 1984). Having one researcher embedded allows for connections to be drawn between different parts of the system. For two academic years, Hannah attended classes, discussion sections, community activities and presentations, and program assessment meetings. She frequently observed and spoke with students informally in the dormitory. The data she collected included field notes from observations of students and program staff, videos of students working together in class and in the dormitory, focus groups, semi-structured interviews, and annual surveys given to students in the program.

Video data collected consisted of students working in groups in class as well as during study sessions in their dormitory lounge. Data were collected consistently throughout the first course in the program: during every instance of in-class group active engagement implementation (n= 11) as well as four separate times during evening study sessions in the dormitory lounge.

Focus groups were held in fall 2014, soon after the students began the program. An invitation to participate was sent to students of interest

Table 1
Data Collection Methods and Participants Involved

Date	*Data Collection Method*	*Number of Students Involved*	*Students Involved*
FALL 2014-16	Field notes	varied	Matilda, Rachel, among others
Fall 2014	Videos in class (n = 11)	varied	Matilda, Rachel, among others
	Videos in lounge (n = 4)	varied	Matilda, Rachel, among others
	Focus groups	6	Matilda, Rachel, among others
Spring 2015	1:1 interviews	4	Matilda, Rachel
	Annual surveys	54 (entire cohort)	All students
Fall 2015	Focus groups	6	Other students
	UTA interviews	2	2 UTAs, sophomores in the LLP
Spring 2016	1:1 interviews	2	Matilda, Rachel

based on observations in class and in study sessions. Thus, the selection was *purposive* and *strategic* (Miles, Huberman, & Saldana, 2013) to engage those students who were likely to be reliable informants of what went on in the classes and study sessions because of their attendance and participation. Participation in the focus groups was completely voluntary. Six students agreed to participate. Each session was audiotaped, transcribed, and analyzed.

A semi-structured protocol (Glesne & Peshkin, 1992) was developed to assess students' perceptions of the program in the focus groups. These questions were designed to allow students to respond and elaborate with their personal experiences and viewpoints. Questions were asked about their impressions of the overall program as well as their specific perceptions of living together and the courses in the program. Some of the questions asked were these: "How does it feel to live together in the ILS LLP housing?" "What do you like or not like about the ILS LLP courses?" and "What do you like or not like about the ILS LLP?"

In spring 2015, one-on-one interviews were conducted with four students. These four were specifically invited because they were all present in particular collaborative learning settings early in their first semester, and they all participated in very different ways. Three of these students had participated in the focus groups in the fall of 2014, and one had not. The interviewer utilized a stimulated recall research procedure (Lyle, 2003) to encourage subjects to recall their thinking during the original collaborative learning session by prompting them with a video. Students were asked questions about how what they saw on the video related to that experience and related experiences.

Survey data were gathered from all 54 students in the cohort in class at the end of the spring 2015 semester. A Likert-scale survey was administered to capture students' perceptions of their experiences in the program. Open-ended questions were included to allow students to explain their survey responses.

Focus groups were held again in fall 2015, at the beginning of the cohort's second year in the program. The invitation to participate was open to all students in the cohort, and participation was voluntary. Six students volunteered to participate. Only one of these students had been in the focus groups in fall 2014, and none had been involved in the interviews in spring 2015.

One-on-one interviews were held again in spring 2016 with two female students of interest. We followed these two students, "Matilda" and "Rachel," to construct case studies of their experiences and expectations throughout the two-year program, and we continued to follow them throughout their undergraduate experience.

Finally, we interviewed two undergraduate teaching assistants (UTAs). UTAs are chosen from among students in the ILS LLP who are further along in the program and who have been successful in the courses in which they supply support. The two UTAs were sophomores when we interviewed them, and they had been first-year students in the program class that made up the bulk of our analysis. These interviews were also semi-structured, with questions designed to get these students' perspectives on the UTA role after having been both students and UTAs.

Data Analysis

To ensure comprehensive data analysis, any and all textual data collected, including field notes, transcripts of interviews and focus groups, survey results, and analytical memos, was compiled into a password-protected digital space. We took an analytic induction approach to address

our research questions (Goetz & LeCompte, 1981; Robinson, 1951). Analytic induction is a continuous process of generating initial hypotheses; scanning a corpus of data confirming and disconfirming evidence; and modifying, restricting, and refining these hypotheses with the analysis of new cases (Erickson, 1986, 2012). Analytic induction is particularly suited for our approach in that it "does not mandate a particular unit of analysis; it is adaptable across unit types" (Goetz & LeCompte, 1981, p. 58).

Based on the ILS LLP's expressed mission of collaborative learning, we adopted a broad initial hypothesis that collaborative learning, consistent with scientific sense-making, was occurring in the LLP and was supported by a set of mutual expectations and practices among LLP faculty, staff, and students. The first author, as a participant observer, continuously reviewed the entire corpus of data, looking for confirming and disconfirming evidence of productive collaborative learning. The first and second authors then reviewed major themes together, discussing emerging themes arising as confirming and disconfirming evidence was analyzed. Because our initial analysis suggested that several factors were operating to mediate productive collaborative learning in these conversations, we focused in on particular opportunities for collaboration for further analysis at the interpersonal level. Analysis of these conversations and refined hypotheses were presented at two different research group meetings in order to make outside checks on emerging interpretations. This analysis at the interpersonal level led us to focus on aspects at the personal and community levels that appeared salient. Further analysis at these levels led to further refinement of our understanding of the influence of the personal and community factors on productive collaborative learning at the interpersonal level of analysis.

Findings

Next we present excerpts from interviews and focus groups, a transcript from a collaborative learning setting, and observations from field notes to analyze collaborative learning in the ILS LLP at different planes of participation.

Interpersonal Plane: Students Working Together in the Dormitory Lounge

This section presents cases of interpersonal collaborative work among students. It makes up the bulk of our findings section because it includes transcripts, and because it is the plane of analysis in which we can observe

productive collaborative sense-making. The first set of transcripts below comes from a video recording of a discussion that occurred in the students' dormitory lounge during a group homework session. These informal, non-mandatory group study sessions were opportunities for students to work together on homework questions for their organismal biology class with support from an undergraduate teaching assistant (UTA). In this example, the students discussed a question assigned by their professor on spontaneous formation of organized life as it relates to the second law of thermodynamics. This question came from the first homework assignment for the first course that students take in the program:

1. Nick: Does anyone want to talk about four?
2. Group: What's that? That's the thermodynamics one. . . .
3. Matilda: Ok. [smiles and looks at her screen] So I think, I think. . . .
4. Nick: Can anyone clarify what the second law of thermodynamics is?
5. [Matilda looks up at the UTA]
6. UTA: Does anyone want to explain it?
7. [Students look around at each other]
8. Matilda: So . . . I mean it's basically that [Matilda offers an explanation for the thermodynamics problem, pausing as she thinks, and making frequent eye contact with others in the group]. . . .
9. UTA: Does anyone else have thoughts?
10. Nick: So does the spontaneous origin of, so I'm assuming the spontaneous origin of biological structures, then, would decrease entropy? Is that, is that what this is implying?
11. Matilda: So, yeah, like the question, like, what it is implying is that, like, spontaneous reactions, I mean that, um, formation of life should not have occurred because. . . .
12. Nick: That decreases it.
13. Matilda: Formation of life is like organizing. . . . [hand gestures to shape a ball]

Several aspects of this transcript suggest that the students were trying to work together to make sense of the problem and construct an explanation. First, Matilda didn't immediately share her own answer as though she knew it for certain, but instead, she responded to Nick's question of whether anyone wanted "to talk about four" (line 1). Nick's follow up question (line 10) demonstrates that he actively considered Matilda's explanation and related it back to his own ideas. Students' verbal and non-verbal communication suggests that they actively engaged in trying to make sense of the problem together. The other students in the group, although they were not verbally participating here, constantly made eye contact with each other, nodded in agreement, and listened intently to the conversation. The UTA encouraged group discussion (lines 6 and 9) without making her own claims.

Later, after another student, John, joined the group, the group returned to the question:

14. Amy: Should we talk more about number four?

15. [The group looks around at each other. Matilda says yes and smiles]

16. UTA: [Makes eye contact with Matilda] Go for it.

17. Nick: Were you here when we were talking about it earlier? [looks at John]

18. John: Oh, no.

19. Nick: So let's rehash what we said then.

20. UTA: Matilda, go for it.

21. Matilda: So what does the second law . . . the second law says that. . . . [Matilda summarizes her earlier explanation]

22. John: Ok, that makes sense.

Here, Matilda shared her ideas again, checking non-verbally for feedback from the UTA and other students. Amy encouraged further group discussion by bringing up the question again after it had been discussed earlier (line 14). It is worth noting that Nick referred to the earlier discussion as "*we* were talking about it" and "what *we* said then" (lines 17and 19). His use of this plural pronoun suggests he recognized that the group worked together to make sense of the problem and construct an

explanation. Again, the UTA encouraged student participation without dominating the conversation (lines 16 and 20).

Later, another student, Rachel, walked into the lounge. Rachel had not been present when Matilda shared her ideas but arrived shortly afterward. She announced the progress she had made on the homework set and offered her explanation for the question based on her discussion with the professor earlier:

23. Rachel: Ok, I have 1, 3, and 4 but not 2.
24. UTA: So we're talking about number four now, and they're just kind of talking about what they discussed so far. . . .
25. Rachel: Oh, [the professor] told me to try to explain to everyone because he spent two hours this morning trying to explain it to me.
26. UTA: Ok, go ahead!
27. Rachel [standing and speaking energetically with ample hand gesturing]: Ok, here we go, um, so the second law of thermo is. . . . [Rachel provides her explanation directly to the seated students]
28. John: Oh, that's the membrane.
29. Amy: The lipid bilayer.
30. Rachel: Mmhm, basically. . . . [Rachel continues her explanation]
31. John: Oh, so like Matilda was saying?
32. Matilda: Yes.
33. Rachel: Please tell me that was. . . .
34. Nick: That was great!
35. [Group applauds]

Rachel finished her description of what she said the professor "spent two hours" explaining to her, and the group applauded as though it were a performance. This applause could be interpreted in several ways. It could demonstrate support for Rachel's attempt to make sense of the question. John does mark Rachel's answer as "like Matilda was saying" (line 31),

suggesting he valued the corroboration. Alternatively, the group's clapping could mean they valued Rachel's delivery of the "correct answer" that the instructor had spent time explaining to her. We don't really know, and students in the group may have been engaging differently—some taking it as sensible corroboration, and some taking it as faithful repetition of the correct answer.

This shifting between collaborative sense-making and less productive collaboration was common in the lounge sessions. For example, a week after this initial session, students were discussing a new homework set, also about the thermodynamics of life. Rachel was involved in the conversation, and Matilda was sitting on the couch, not part of the conversation, but apparently listening in.

In the first segment, the students were discussing the following question:

> 2A. Jack claims that one way of accurately determining the amount of free energy of the light energy absorbed during photosynthesis is to measure the free energy in all the glucose synthesized during photosynthesis. Provide additional information to support or refute Jack's claim.

1. Mike: Ok. 2A.
2. Danielle: I wrote false because it doesn't account for the energy lost as heat.
3. Rachel: I feel like I don't have enough, but all I wrote for 2A was no because a ton of energy is diverted.
4. Mike: So only heat, though.
5. Kristen: All I said was that. . . . [inaudible]
6. Rachel: Yeah, I literally have like one sentence. I feel, I mean, I don't know, like what else is there to say? Is there anything I'm missing?
7. Sarah: Um, I didn't hear you; what'd you say?
8. Rachel: For 2A all I have is one sentence saying that it doesn't account for the fact that a ton of energy is lost as heat.
9. Sarah: Um, yeah, I said that and more background information, like no process is 100% efficient. And that energy is converted to a usable form.

10. Kristen: Energy is converted to what?
11. Sarah: A usable form.
12. Mike: So for 2A I said his claim was false.
13. Rachel: [looks up at group] Are we ok with 2A?

In the discussion about problem 2A, we see little evidence of students' engaging in productive sense-making in collaboration. The discussion here was primarily concerned with determining if they have "enough" information in their answer, as Rachel said (line 3). Sarah provided a little more "background information" (line 9), which apparently satisfied Rachel, who checked in with everyone (line 13) to ask if they were now "ok with 2A." One possibility is that the nature of the questions contributed to the students' concern about the amount of detail they were providing, because the question specifically asks them to "provide additional information." It's also possible that Rachel's comment reflecting an expectation that their task was to generate enough information (line 3) may have derailed a potentially fruitful conversation.

As the conversation continued, the students began to work on the next problem:

> 2B. Certain organisms, such as the fire flies frequenting Maryland backyards during summer months, can produce light via a process known as bioluminescence. For background information, read the following website: http://en.wikipedia.org/wiki/Luciferase. Does the ability of fireflies to make light violate or not violate the Second Law of Thermodynamics? Explain your reasoning.

This next transcript begins after the students began to discuss the question, focusing in on how an increase in the number of molecules led to greater disorder and, therefore, did not violate the second law of thermodynamics. The UTA jumped in:

1. UTA: Ok, so you guys are on the right track with the number of molecules. . . .
2. Rachel: Since it's activated the thing, it uses that energy because it goes back to the ground state, but. . . .
3. UTA: Oh, you're talking about when the electrons first get excited, right?
4. Rachel: Yeah.

5. UTA: Sorry, can you elaborate. [Matilda, sitting on the couch, turns around to face the group]
6. Rachel: So I forget what it's called, but there's like the thing when. . . .
7. Mike: They jump right . . . to an excited state.
8. [All students talk at the same time]
9. Rachel: And then they lose that energy.
10. Mike: They lose that energy.
11. Kristen: They release that energy.
12. Rachel: And that's the energy lost.
13. Kristen: That is the light creation, because when they drop it makes the light.
14. Rachel: Ok, but. . . . [looks to UTA, appears frustrated that other students continue to cut her off as she tries to form her ideas]
15. Mike: So the energy put into it. . . .
16. UTA: Is that energy . . . when the electrons are returning back to ground state, is that energy lost or is that transformed?
17. Kristen: That's transformed into light.
18. Mike: So that's the light, right?
19. Rachel: [to the UTA] So is there any heat released?
20. UTA: Yeah.
21. Mike: Not a lot, though.
22. Sarah: Wait, can we always measure heat as like a measure of efficiency? Like if the process is really exothermic. . . .
23. Mike: What if the purpose of the process is to create heat?
24. Matilda: [from the couch, turned around to face the

group] It's not really inefficient, but if heat is released, heat is an unusable form of energy.

25. Kristen: Why does heat count as unusable form of energy?

Here we noticed a shift from the students' discussion about whether they had enough information for question 2A. The conversation now focused more on the substance of question 2B, and several students were enthusiastically sharing their ideas, but the conversation was strongly influenced by the presence and direction of the UTA. The UTA grabbed Rachel's attention when she told the group that they were on the right track (line 1). Rachel then attempted to make sense of the question; however, she responded directly only to the UTA (lines 2, 4, and 6), and she directed her later follow-up question only to the UTA (line 19). The UTA directly responded to Rachel (line 20) and confirmed her answer. Rachel was visibly frustrated when other students formed ideas out loud simultaneously, but the other students appeared excited to work off of each other's ideas. Matilda, who was not even sitting at the table with the group, turned around to listen in on the conversation and enthusiastically volunteered to share her idea (line 24) to add to the group discussion. Overall, this transcript demonstrates that even when productive sense-making appears to be occurring in this LLP, different students will engage differently in the conversation, and the conversation is impacted by the participation of the UTA.

We present these cases, highlighting the shifting modes of collaboration, to show some of the diversity of interactions that occurred in the ILS LLP. Other transcripts show that students predominantly engaged in productive collaborative learning, particularly in the lounge during the organismal biology course. In other transcripts, collaborative learning does not appear as productive, either because of the ways in which the students interact or because of the nature of the task or question. Consistent with our initial broad hypothesis, we observed many examples of collaborative sense-making. However, our observations, and particularly the tendency for collaborative learning to shift from more to less productive, or vice-versa, forced us to elaborate on our initial hypothesis and explore factors that influenced these shifts in collaborative learning behavior. Several of these factors that appeared salient in the students' interaction were the individual students' expectations for collaborative learning, the behavior of the UTA, and the students' interactions with the professor.

Personal Plane: Matilda's and Rachel's Personal Expectations for Collaborative Learning

In this section we focus on the individual perspectives of two students, "Matilda" and "Rachel," who were present in the collaborative learning settings analyzed above. We explore their personal expectations for collaborative learning, based on their actions in the collaborative learning settings, as well as their responses in interviews and focus groups later on. Although we focus on the expectations of these two students, we are not arguing that these are the only possible expectations expressed by students in the collaborative learning setting. It would be challenging, if not impossible, to describe all of the various types of expectations that students may bring to a collaborative learning setting. Rather, we see value in concentrating on two students who generally seem to bring different expectations that, in turn, seem to have had the greatest effect on the outcome of the collaborative learning situation. We also are not attempting to characterize either student as someone who always holds certain kinds of expectations, but rather to highlight the differences in participation in the collaborative learning settings we have described and to trace the possible influences and consequences.

Matilda: "The End Product Is Being Able to Fully Understand It."

Based on her behavior during the collaborative discussions above, we believe Matilda expected she should be trying to work with others to make sense of the problem. In the first discussion, about the spontaneous formation of organized life, she proceeded hesitantly with her explanation, as though she were trying out a possible response. This is more obvious in the video, where Matilda clearly looked for permission to continue from the UTA and made eye contact with others in the group. In informal conversations with the first author, and in focus groups and interviews, Matilda frequently mentioned her appreciation for being able to explain things to her fellow classmates and how that helped her to learn. As she said in the focus group, "I like that we're all explaining things to each other, because when I hear someone explain it to me, I then understand once. Then when I can explain it to someone else, it reinforces it for me so, like, I understand it a lot better."

Matilda appreciated the dormitory lounge as a place where productive collaborative learning could occur. She attended group study sessions multiple times for the same assignment, looking forward to discussing her answers even after her assignment was complete, apparently always

wanting to understand better the concepts by talking it through with others. She said in a focus group, "Every time I heard someone talk about something or every time I try to explain it, I understood it more and more, so like the end product is being able to fully understand it." Matilda even expressed feeling "guilty" about not being able to go to the lounge to study with others when she was sick. It's notable that even though she was not sitting with the group during the second lounge session (the discussion of questions 2A and 2B), she was present in the lounge and turned around to listen in and contribute.

Matilda shared with the first author that being able to work collaboratively on assignments strengthened not only her understanding of biology, but also her relationships with her peers. She found comfort in working this way and appreciated the collaborative elements of the LLP. She valued the collaborative learning space that the lounge created. As she said in an interview, "Just being in the environment working with other people is nice, even if you're not working on the same thing." During the second class in the program, which did not encourage much collaborative work, Matilda felt unsure how to study and appeared to miss many of the main ideas of the course, going so far as to mention that "there are no big ideas in genetics." Her uncertainty of how to make meaning in this second class emphasizes how Matilda valued collaborative learning and believed that it was a productive way for her and her classmates to learn.

As we have continued to follow Matilda, we have continued to see her proclivity toward working collaboratively with others. During her sophomore year, Matilda continued to study in the lounge on the floor as well as in other areas of the building, and she appreciated being able frequently and casually to discuss coursework with her roommates and neighbors. When Matilda discussed content from the first sophomore course, the discussions were "not necessarily just with the people in my group from class, but with anyone on the floor."

Rachel: "At Least One Person Is Going to Know Each Problem."

We see Rachel's "performance" during the collaborative learning session as a reflection of her expectation that she had become an "expert" on this question by virtue of having had the correct answer explained to her by the instructor. Notably, the professor's recollection of his conversation with Rachel is that they were *discussing* the problem, and he was consciously *not* trying to guide her. Rachel saw it differently, reiterating, in an interview about the lounge conversation, that the professor had explained the problem to her, and that she saw it as her obligation to share it. "He was really helpful in explaining that last question about entropy,

and I guess I went to the lounge to double check my answers and go over number four with other people, because I felt it was unfair because he explained it to me really well and other people didn't get that explanation."

Rachel apparently expected that the collaborative sessions in the lounge were opportunities for people to share correct answers. As she said about these sessions in the focus group, "It's wonderful because at least one person is going to know each problem right? And they're gonna help other people through it." She would bring her assignments to the lounge the night before they were due to "check answers," as she said, to hear what other people had to say about questions she hadn't answered, and to get confirmation that she would get credit for her answer. For example, in the discussion above about problem 2A on the second thermodynamics homework, Rachel asked a fellow student the following: "I feel like I don't have enough, but all I wrote for 2A is 'no' because a ton of energy is lost as heat. I literally have one sentence. I feel, I mean, I don't know what else is there to say?"

In general, Rachel rarely appeared to collaborate spontaneously, often sitting alone in class, even when the professor encouraged group discussion. She asked for help from the professor or UTA rather than working with the students around her. Unlike Matilda, Rachel did not seem to expect that collaborative learning was an opportunity to construct knowledge with other students. Instead, she seemed to expect that working with others was a means to getting answers that she couldn't get on her own.

As with Matilda, our interpretations of Rachel's expectations for collaborative learning seem consistent with her continuing progress in the program. Unlike Matilda, Rachel did not appear to value collaboration, or expect that it could aid her understanding of the material. When asked if she still works with other students in the program outside of class, she responded "not really," claiming that the sophomore-level classes in the program don't challenge her enough for her to find it necessary to work with others: "It takes me much longer to try to find a group of people than to just spend the time to go through it myself."

We present the cases of Matilda and Rachel, again, not to make broad generalizations about how students approach collaborative learning in the ILS LLP, or even to essentialize Matilda and Rachel as people who always hold certain kinds of expectations for collaborative learning. For example, while Matilda primarily expressed an expectation that collaborative learning supports the understanding of concepts, in at least one context (described in the section below) she did not appear to expect that collaborative learning would be productive in this way. Rather than treating Matilda and Rachel's expectations as unitary and unchanging, we

present these cases to demonstrate that there are diverse ways in which students may approach collaborative learning and that this diversity can influence what occurs in collaborative learning settings. It is interesting to note, however, that the expectations that we highlighted with the cases of Rachel and Matilda appear to be expectations that each of them has carried with them as they've moved forward in their academic careers.

Community Plane: The Effect of Structure and Power Relations on Collaborative Learning

Through the lens of our framework, we consider collaborative learning to be constrained and afforded by structure and power relations in the ILS LLP community. Faculty and staff communicate course expectations, learning goals, mission, and objectives of the program, including to "create a living-learning community that fosters collaboration," as worded in the program mission. Upper-level students serve as undergraduate teaching assistants for classes, acting as role models and encouraging productive reasoning during collaborative learning settings. Group dynamics among the cohort also have an influence on how collaborative learning is enacted in the LLP and who is involved.

Faculty and Staff

Faculty and staff may encourage or derail productive collaborative learning, depending on the goals and expectations they communicate to students, the ways in which they interact with students, and their pedagogical choices. The director of the program, who also teaches the first course, encouraged collaborative learning by including group work in class and explicitly directing students to work on homework in groups. The transcripts included earlier were from one of these group homework sessions. When asked about this course during an interview in the semester after it was over, Nick remembered, "I think he [the professor] encouraged it during class. . . . And I think he said like . . . make sure . . . like he wanted us to collaborate on it. So, otherwise, that like culture of coming to the lounge and working with other people would not have been established."

The approach of the professor in the initial course is consistent with our initial hypothesis that productive collaborative sense-making was supported by the program. Our analytical approach to search for disconfirming examples drew our attention to the second course in the program and its impact on collaborative learning. The faculty member who teaches

this genetics course, was not focused on encouraging collaborative learning, despite the program's emphasis. The course was taught in an entirely lecture-based format, with no room for student participation and questioning and no opportunities for students to work together. The instructor did not assign group homework assignments and did not encourage students to study together outside of class. This had a direct effect on the students' behavior. When asked about this course, Nick stated, "No one comes to study group sessions [in the lounge] this semester, and I don't see that changing." This demonstrates that the way faculty teach their courses and the messaging they provide can derail the system that was established, even if the conditions for collaboration within the community already are in place.

Matilda made a comment about the genetics course that we found to be particularly revealing, "We definitely work together less than last semester. Again, I just think it's because there aren't very many big concepts in genetics, so, like, I don't know, like . . . so for me, I guess, like, I don't know what I would discuss with people . . . because it's basically a lot of factual information." It is surprising that Matilda claimed that "there aren't very many big concepts in genetics"; most scientists and science educators would disagree. Big concepts in genetics include, for example, the laws of segregation and independent assortment, the cytological bases for these laws, and the models of genetic population dynamics. It may be that Matilda was referring to her genetics course and not to the study of genetics as a subject, which emphasizes the point: The faculty member's pedagogical choices, including his unwillingness to encourage the students to make meaning collaboratively, unintentionally communicated an unproductive epistemological stance toward genetics and, potentially, toward science in general.

During a focus group in their second year, other students recalled similar things about their first year courses: "I think for genetics it was very self-studying. Like, I sat in the lounge and did it all on my own, but for organismal biology, like, if you wanted to you could actually collaborate on it, because it was a class that kind of inspired collaboration, because [the professor] was always like, you know, 'work with students,' so you just kind of had this natural feeling that you could." This student used the living-learning space, the lounge, to study for the program courses. However, because the student was no longer in the course that "inspired collaboration," she didn't feel that she could "actually collaborate."

Undergraduate Teaching Assistants (UTAs)

Similar to faculty and staff, UTAs may encourage or derail productive collaborative learning, depending on their own expectations and how

they respond to the expectations of the students they are working with. In the first transcript, the UTA was careful not to interject with her own ideas, but instead encouraged group discussion and balanced group dynamics. Matilda may have looked to the UTA for encouragement, but she did not depend on the UTA for an explanation. This was reiterated when she stated in a focus group, "We all kind of try to figure it out together, and then we will all look at the UTA, and then she either nods her head or goes, 'Hmm, why don't you guys think about this?'"

However, other students may have different expectations for the role of the UTA. Also, other UTAs may have different expectations for their role, causing them to interact with the students differently. A student in a second-year focus group remembered from first semester, "I felt uncomfortable talking to other students, because I didn't trust them to know the answers. It was a lot easier to just go straight to the UTA and have them lead me through the answers." We have observational evidence that some students went to the UTA in class and out of class in place of attempting to discuss biology with their peers. Some UTAs, typically the younger, less experienced ones, fed into student requests and led them through problems. Other UTAs responded with productive questioning, such as "What have you discussed in your group about the problem?"

Two of the students from the cohort being followed became UTAs for the first-year course as second-year students. They shared insight into the perceived role of the UTA during their first year compared to how they saw themselves in the role: "Some of the TAs last year . . . we'd kind of just go through the homework together in a group, which I thought was helpful but probably wasn't as helpful as just sitting there and working it out . . . and so I think I'm a little bit less willing to, like, give them the answers and tell them what's right and what's not this year." The UTAs met with the course instructor weekly, and he continuously directed them to attend to students' thinking and encourage students to reason through problems. The UTA described these intentions when she said, "[The professor] really emphasizes reflecting all of the discussion, like the thought back to the students. He tells us, 'Don't give them the answers; they need to come up with them themselves.'"

Student Identities in the Community

The ways in which the program structures opportunities for collaborative learning fosters students' developing social practices, but at the same time, we suggest that students' engagement in collaborative learning helps to build and support the cohesion and collective identity of the living-learning community. One student summed this notion up quite well when

he stated, "The emphasis on collaboration helped form a bond between peers and establish group study habits." However, if students don't feel a strong sense of belonging in the community, they may not be as likely to participate in collaborative learning. For example, one student in a second-year focus group stated, "I can't speak, because I'm not in 'that group' of people in ILS, but they like doing stuff together and working together from what I've seen."

We can tie the relationship between student identity in the community and collaborative learning back to our examples of Matilda and Rachel. During her sophomore year, Matilda chose to continue living with her roommates in the dormitory building that houses the ILS LLP. She remained very close with many people in the program who also stayed in the same dormitory. She refers to the program as a "family" and shared in an interview that "It's just a nice feeling to have that community." Rachel chose to move out of the dormitory building that houses the program for her sophomore year. She claimed that "Personally, I didn't click with anyone in ILS. My friend group is not from ILS." These two students' expectations for and participation in collaborative learning may have impacted the development of their identity in the overall community.

Exploring collaborative learning in the LLP at these three planes of analysis gives us a broad picture of where, when, and how productive collaborative learning can occur, how individual student expectations may influence it, and how it can be shaped and constrained by aspects of the community. We turn now to a discussion of our findings and the significance of this work.

Discussion and Significance

There is an assumption, and emerging evidence to support it, that collaborative learning opportunities can be productive for undergraduate science learning. Collaborative learning also plays a major role in connecting academic and social experiences for undergraduate students, which is extremely important for an LLP. This article takes a closer look at collaborative learning in a life sciences LLP. We seek to understand, as described in our research questions, how collaborative learning occurs in an LLP, particularly one with an expressed focus on collaboration, and how personal, interpersonal, and community factors constrain and afford its occurrence and quality.

Through an ethnographic approach and analytic induction, we have formed an image of this LLP as a community in which collaborative scientific sense-making can and does occur, but our data suggest that a variety

of factors influence how, when, and to what extent. In the transcripts of collaborative learning settings that we have presented, we demonstrated how conversations often shift from productive collaborative sense-making to sharing of answers, or requests for more detail. We have argued, through the case studies of Matilda and Rachel, that these collaborative learning settings reveal different expectations that students bring to these settings, and that these expectations help to form the interactions. The shifts in the interactions not only may be influenced by students' expectations, but also may influence how students' own expectations shift, either during the interaction, or in different kinds of settings in the LLP, and over longer time spans.

In line with similar research on student expectations (Danielak et al., 2014; Hall, 2013; Redish et al., 1998), we predict that some collaborative learning expectations are more productive for science learning than others. The ILS LLP leadership goes to great lengths to communicate productive collaborative learning expectations: It is emphasized in several courses taught by program faculty and staff, UTAs are trained to encourage sense-making discourse in group sessions, and the use of collaborative learning spaces such as the lounge is encouraged. Our case studies suggest, however, that students' expectations may contribute to whether and how they "take up" these programmatic expectations. Better understanding the diversity of students' collaborative learning expectations will help the leadership of this program, and other undergraduate educators, think about how to structure collaborative learning opportunities to promote productive expectations and, thus, promote productive collaborative learning.

Our findings also demonstrate collaborative learning is constrained and afforded by structure and power relations in the community, including faculty and staff, undergraduate teaching assistants, and overall group dynamics. If we were to consider this LLP a "community of practice" (Wenger, 1999), members of the community would mutually engage in the goal of supporting students in collaborative learning. Faculty and staff play a large role in setting the norms for the ILS LLP; therefore, coherence and consistency among faculty is key. Our findings suggests that establishing a focus for collaborative learning may not be enough if the program doesn't sustain the message. In the case of this LLP, we have shown how the traditional structure of the genetics course derailed an orientation toward collaborative learning that had begun in the organismal biology course, even for students with generally productive expectations like Matilda. We suggest that if programs wish to create a "community of practice" that values collaborative learning, members of the community

must have a shared vision for what this community looks like and be proactive in enacting and sustaining that vision.

This study is not without its limitations. Our descriptive, qualitative study analyzed collaborative learning from one specific program, focusing in on specific instances of students working together in one course at one point in time. One could argue that, because of this, our findings are not generalizable. However, we would agree with Eisenhart (2009) that "there are numerous, well-established ways of approaching generalization from qualitative research" (p. 65). For example, while our approach did not allow us to quantify student expectations or uncover an exhaustive list of possible student expectations, we were able to provide detailed examples of student expectations that likely are common. We are planning to collect survey data that will give us more insight into a broader variety of student expectations, so that we could better apply what we have learned through a detailed analysis of two specific students to a larger population. For this purpose, we are modifying the Maryland Biology Expectations Survey, or MBEX (see Hall, 2013), to look specifically at students' expectations for collaborative learning.

This work is significant in that there has been very little qualitative exploration into collaborative learning in LLPs. In this sense we hope it can be generalizable in method and theory, if not in findings. Applying ethnographic methods and analytic induction to other living-learning programs, especially those that support students from diverse backgrounds, could provide insight into the cultures of a variety of LLPs. We intend for our work to provide a starting point for others wishing to pursue this line of inquiry, and we welcome the reproduction, challenges, or elaboration of our findings as well as the modification and enhancement of our developing framework. More descriptive studies of the outcomes of LLPs are needed, particularly with more diverse groups of students.

Our findings have clear implications for development and operation of LLPs: Program developers must work to establish a clear and transparent articulation of what they are trying to accomplish, and then enact a systemic approach to ensure that program goals are being met. Program coordinators can't just consider the mission of the community; they must consider how to engage all members of the community in promoting and sustaining the mission. Instructors and teaching assistants need support to see beyond their classrooms and study sessions—to see beyond their standard operating practice and to participate in the community in ways that align with its mission.

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