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Why STEM Learning Communities Work: The Development of Psychosocial Learning Factors Through Social Interaction

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Abstract
STEM learning communities facilitate student academic success and persistence in science disciplines. This prompted us to explore the underlying factors that make learning communities successful. In this paper, we report findings from an illustrative case study of a 2-year STEM-based learning community designed to identify and describe these factors. A directed content analysis of 119 student narrative documents resulted in 6 content codes organized into two primary categories: *academic self-regulation*, *STEM identity*, *metacognition*, and *self-efficacy* comprise the psychosocial or 'affect' learning factors that students identified as improved as a result of their participation in the learning community; and *interaction with faculty/staff/STEM professionals*, and *interaction with peers* represent the aspects of the learning community that students identified as meaningful learning community experiences related to their academic development. In addition, we analyzed 3 sets of code co-occurrences to understand how the content codes interrelate. Our findings indicate that certain psychosocial learning factors are developed through social interactions within the context of learning community participation, which may help explain the positive effects of student participation in learning communities.

Keywords
STEM Education, Psychosocial Learning Factors, Sociocultural Theory

Cover Page Footnote
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Science-based disciplines on college campuses struggle with high failure rates in classes, low student retention rates in majors, and lower than average degree completion rates (Windsor, Bargagliotti, Best, Franceschetti, Haddock, Ivey, & Russomanno, 2015; President's Council of Advisor's on Science and Technology, 2012; Committee on Underrepresented Groups and the Expansion of the Science and Engineering Pipeline, 2011). A popular intervention has been the implementation of STEM-based learning communities, which have been found to facilitate academic success and increase retention and graduation for students in science-based fields (Dagley, Georgiopoulos, Reece, & Young, 2015). The success of STEM learning communities prompts us to explore the underlying factors that make these communities successful mechanisms for increasing student academic performance and commitment to STEM careers.

First, we review the literature on STEM learning communities and the theoretical frame that undergirds learning communities—the view of teaching and learning as fundamentally social activities. We then discuss the research on psychosocial learning factors, or "affect" factors, and their role in facilitating STEM academic success. Next, we present the results from our case study of a multi-year STEM-based learning community designed to explore these factors. We conclude by framing our findings as supportive of a conceptual framework that places social interactions as the catalyst for psychosocial learning development, which may be the key underlying force that explains the positive effects of student participation in learning communities.

STEM Learning Communities and the Social Nature of Learning

Learning communities (LCs) have become part of the higher education landscape. LCs are organized academic communities focused on a theme relevant to students including academic interests, major, and/or student characteristics. Students who participate in an LC are often housed together, take academic classes together, and are provided with educational and cultural programs to enhance the academic curriculum and social integration. The purpose of STEM LCs is to recruit, develop, and retain students in STEM disciplines and to increase student academic success, graduation rates, and post-graduation participation in STEM fields.

Learning communities are considered high-impact programs, and STEM-based learning communities have been found to predict academic achievement and increase persistence rates (Dagley et al., 2015; Kuh, 2008: Pasque & Murphy, 2005; Heaney & Fisher, 2011; Inkelas, 2012). LC participants earn higher GPA's than non-LC participants (Baker & Pomerantz, 2001), have higher graduation rates (Hill

& Woodward, 2013), report higher levels of satisfaction with college experience (Zhao & Kuh, 2004), have higher levels of academic self confidence (MacPhee, Farro, & Canetto, 2013), and are overall more academically engaged (Pike, Kuh,& McCormick 2011; Rocconi, 2011).

While learning communities have been around since the mid 1980s (Smith, MacGregor, Matthews, & Gabelnick, 2004), the articulation of informal science education is relatively new area for research in STEM education (Fenichel & Schweingruber, 2010; Bell, 2009). Informal learning environments can include everyday experiences, designed settings outside the classroom, and program settings. STEM learning communities are classified as program settings for informal science education because they complement formal settings yet operate outside them (Kotys-Schwartz, Besterfield-Sacre, & Shuman, 2011). Rahm, in a 2014 commentary in the *Journal of Research in Science Teaching*, presents a vision for this emerging field that calls attention to relational learning, student identity, and affect factors, all of which constitute a more nuanced approach to complex learning practices. This paper aligns with Rahm's goals.

Learning communities, by their very definition, provide a structure for social interactions between and among students, their peers, and faculty, staff, and STEM professionals. The theoretical perspective undergirding learning communities is what Kenneth Tobin (2012, 2015) calls a "sociocultural perspective." This perspective on learning highlights the social forces that affect learning, including how students learn with others, through others, and from others, as well as the importance of collective relationships and social networks to an individual's outcomes (Scott & Palincsar, 2014). A sociocultural theory of learning shifts from teacher-focused views of education to the centrality of the interaction between teachers and students in teaching and learning activities. This theoretical framework has driven numerous pedagogical shifts in the university classroom such as flipped and inverted classrooms, peer-assisted learning, problem-based learning, collaborative learning, cooperative learning, active learning, and experiential learning (Bishop & Verleger, 2013; Jonassen & Easter, 2012).

Lev Vygotsky (1986), a prominent Soviet psychologist and early sociocultural theorist, argues that human beings are social beings, and that all development, growth, and learning come from experiences relating with others. Social interaction is not just important but *necessary*, because we learn—and "become"—through dialogue with others. His focus on the social aspects of learning stands in contrast to more individualistic theories of learning, including cognitive theories that focus on aptitude and individual learning styles.

As class sizes continue to increase and more students take classes online, the traditional classroom environment consisting of a teacher face-to-face with a small number of students is becoming rare, particularly in the first few years of study. This limits the interpersonal interactions in the classroom. This trend, coupled with high failure rates and low student retention rates in STEM majors, has driven the work to develop informal science learning environments. The success of STEM learning communities prompts us to explore the underlying factors that make these communities successful mechanisms for increasing student academic performance and commitment to STEM careers.

Psychosocial Learning Factors ("Affect" Variables)

Student performance is a complex phenomenon. Researchers attempting to understand and influence student academic performance have studied student attributes (e.g., intelligence), teacher attributes (e.g. immediacy), curriculum (e.g. scaffolding), classroom factors (e.g. size), and pedagogical strategies (e.g. peer-learning). Social interactions and psychosocial learning factors (affect variables) comprise a host of other factors that influence how students perform academically.

Psychosocial factors have been under-researched in STEM education in favor of more cognitive and behavioral factors (Smith, 2010). However, there are a number of compelling reasons why STEM education researchers should be concerned with psychosocial learning factors. First, there is a strong relationship between affect variables and academic achievement (see Gungor, Eryilmaz, & Fakioglu, 2007; Clifton, Perry, Roberts, & Peter, 2008; Clifton, Perry, Stubbs, & Roberts, 2004; Von Stumm & Ackerman, 2014). Second, women, some ethnic minorities (African American, Latina/o, and Native American), and socioeconomically disadvantaged students in the United States are underrepresented in many STEM educational fields and occupations (MacPhee et al., 2013; National Science Foundation, 2013). Some research indicates that psychosocial factors, such as academic self-efficacy, are lower in underrepresented groups, causing them to be less likely to persist in STEM career paths (Haynes, Perry, Stupnisky, & Daniels, 2009; MacPhee et al., 2013; Starobin & Laanan, 2008; Schunk & Pajares, 2005; Cech, Rubineau, Silbey, & Seron, 2011). For example, Kendricks, Nedunuri, & Armet (2013) found that a nurturing community environment facilitated positive self-concept and self-efficacy in minority students at an HBCU and that participants reported that their relationships with their mentors was the most influential factor in their academic success. A focus on psychosocial factors is particularly relevant for addressing the success of underrepresented groups in STEM fields.

The psychosocial learning factors discussed in this study are: students' sense of self-efficacy, metacognitive skills, academic self-regulation, and professional identity.

Case Study: AToMS and IMS Learning Communities (2012-2014)

In order to explore the role of various learning factors and experiences for student development in the context of a learning community, we conducted a systematic illustrative case study of a multi-year STEM learning community designed to increase student persistence and academic success in STEM courses. An in-depth case study can describe what occurred and why as well as suggest areas for future research. An illustrative case study extends the scope by providing examples of theoretical arguments and propositions—an important aspect of theory development (Levy, 2008). We structured our research to provide both rich descriptions as well as data for conceptual framework development.

The data from this case study does not offer student success outcomes related to student participation in our learning community. While measurable outcomes are important, our focus was instead on identifying learning processes that might support academic success outcomes. In this way, we hope to contribute to the broader understanding of how learning communities function to support learning and persistence.

Research Method

Learning communities are clearly successful as interventions for STEM persistence and success, but why? Our curiosity about what aspects of learning community participation account for student development led us to ask the research question: *What activities, or aspects, of the the learning community do students identify as catalysts for their academic development and/or success?*

Learning communities are multi-faceted and time and resource intensive, typically offering students a common course, common living quarters, social activities, content-based presentations, peer mentoring, lunches with faculty, etc. If we can identify the core components of learning communities that facilitate student psychosocial development and attempt to understand the role they play in the development of affect factors, we can better understand why they function to support student academic success and how we may be able to replicate them in other academic learning environments.

Program Description

AToMS (Achieving Together in Math and Science) and IMS (Innovations in Math and Science) were STEM-based Living/Learning Communities (LLCs or LCs) that were developed and implemented by science faculty at a large, public university in the southeast for the years 2012-2014. These LCs created an informal learning environment for students in support of their academic success in STEM fields and were funded through the Office of Learning Communities.

The AToMS and IMS Living/Learning Communities served as an academic support system that included in-depth advising, reserved seats in high-demand courses, a curriculum tailored to their developmental needs, discussion sections led by high-achieving upperclassmen, and rich co-curricular activities with peers and faculty.

Students self-selected into the LCs at orientation, and the initial population consisted of 44 students from Chemistry and Biochemistry, Mathematics, Physics, and Computer Science. In both years, the populations were diverse in race/ethnicity, major, and gender. Students were required to enroll both in a lab section specifically for LC participants and also in Chemistry 11 and 112. Students who chose to live in LC housing were placed in a common residence hall while other students lived elsewhere on campus or commuted to campus.

In the first year, the LC offered chemistry review sessions and a weekly newsletter with upcoming events, deadlines, and opportunities; two Peer Academic Leaders (PALs) were also utilized. The English department offered a STEM-specific course with seats reserved for AToMS students, and several lunches were held for all students, faculty, and staff involved in the LC. A comprehensive evaluation of the first year of the LC was conducted by a faculty member in the Education Research Methodology Department, and the students were interviewed at multiple points across the year. The information gleaned from these data sets informed the planning for the second year.

Recruiting for the second academic year (2013-2014) was more focused and comprehensive, resulting in a waiting list for both the community and the common housing. The lab course was revised to include professional development and a community service requirement, and classes and activities were held in the common dorm. Weekly newsletters and a community blog offered students suggestions for personal and professional development, as well as offering encouragement and reminders regarding course assignments. A final program evaluation was conducted, mirroring the mid-term evaluation protocols.

Shared living space allowed students to form ad-hoc study groups and to enhance their social bonds. Since some classes and Friday lunches were also held in the dorm, students enjoyed the stability of the common space. Shared coursework, extensive personal support, informal faculty mentoring, Friday lunches, and community service opportunities helped build the community.

Data and Analysis Protocols

Data was collected across two academic years (2012-2013 and 2013-2014) to respond to the research question. We analyzed 119 student narrative documents: 33 self-reflection papers written by learning community members at the end of the second year; 52 journal entries submitted by students across the two years; and 34 interview transcripts from participant interviews across the two-year span. All available student documents were included for analysis purposes. As a result of student attrition, not all participants submitted all types of documents; however, we believe the documents offer an adequate representation of student experiences.

We conducted a directed content analysis of the 119 student narrative documents in multiple phases. The goal of this approach is to validate or extend a theoretical framework or theory and thus utilizes existing theory to help determine the initial codes (Hsieh & Shannon, 2005). In the pre-analysis phase, we developed an initial codebook based on the literature and our interest in psychosocial variables. Twelve initial codes guided our initial analysis: *mastery experience, growth mindset, fixed mindset, internal attribution, external attribution, engagement, interaction with faculty/staff/STEM professional(s), interaction with peer(s), metacognition, academic self-regulation, STEM professional/science identity,* and *self-efficacy*.

In phase I of the content analysis, we uploaded the documents into *DeDoose*, a web-based application for analyzing qualitative data. Then we reviewed each document, highlighting content-rich excerpts from the documents and attaching one or more of the 12 codes to each excerpt. In total, we selected 422 excerpts from the texts and attached 647 codes to these excerpts. More than half of the documents, 61% percent, had more than one excerpt highlighted for the content analysis, and 49% of the excerpts had more than one code attached.

We asked two colleagues to assist us with inter-rater reliability testing by independently coding random excerpts using the code definitions presented in table 1. Pooled Kappa coefficients were calculated to evaluate inter-rater agreement; the results were .46 and .58. Generally, values of Kappa from .40 to .59 are considered moderate and .60 to .79 substantial (Landis & Koch, 1977). While agreement was moderate, this is acceptable because few codes were employed (making Kappa values lower) and the raters had no experience with the code terminology other than the brief definitions contained in Dedoose. We believe that more extensive code delineations would have yielded higher agreement coefficients.

At the end of phase I, we eliminated 6 of the original 12 codes because there were too few applications to provide adequate examples for analysis. For example, *mastery experience* was applied to only seven excerpts (less than 2% of the total), which offers too few examples from which to draw a general understanding of students' experiences with subject mastery. The other five codes that were eliminated include *growth mindset*, *fixed mindset*, *internal attribution*, *external attribution*, and *engagement*: each had fewer than 70 code applications, or less than 10% of the total code applications. In addition, we considered each except for content that was not reflected in the initial 12 codes. No new codes were added. The final 6-item code set and code definitions for the data analysis is in Table 1.

Table 1
Final Codes and Definitions

Interaction with faculty/staff/STEM professionals	Student described a social or academic engagement with a faculty member, staff member, or STEM professional (guest speaker, advisor, etc.).
Interaction with peer(s)	The student described a social or academic engagement with another student considered a peer.
Metacognition	The student described thinking about cognitive processes, or an awareness or understanding of their thought processes associated with learning.
Academic self-regulation	The student talked about planning, monitoring, directing, and/or evaluating their own actions toward learning; and/or indicated an awareness of controlling their actions around learning.
STEM professional/science identity	The student self-identified as a member of a STEM profession, a scientist, or as a STEM major.
Self-efficacy	The student stated a belief in their ability to succeed in a specific, STEM-related situation.

In phase II of the content analysis, we reviewed the six codes to look for patterns. We organized the codes into two categories based on the nature of the excerpt content the codes represented: Psychosocial Learning Factors and Learning Community Experiences. The a*cademic self-regulation*, *STEM identity*, *metacognition*, and *self-efficacy* codes reflect psychosocial or affect learning factors that students identified as improved as a result of their participation in the learning community; the *interaction with STEM faculty and staff*, and *interaction with peers* codes represent the aspects of the learning community that students identified as significant and/or meaningful experiences within the learning community.

Table 2
Analytic Categories and the Codes that Comprise Them

Psychosocial Learning Factors	*Learning Community Experiences*
• Academic self-regulation • STEM professional/science identity • Metacognition • Self-efficacy	• Interaction faculty/staff/STEM professionals • Interaction with peers

In phase III, we analyzed "co-occurrences," which included discovering which codes partially or completely overlapped, resulting in an excerpt that had more than one code attached to it, and then re-analyzing the excerpts. The goal of this analysis was to understand how the participants connected the codes. The associations they make give us clues about how factors relate and function to shape participant perception and experience. This type of analysis allows not only for a deeper level of understanding than just what students associate with the participation in an LC but also for an understanding of *how* these constructs might function—the dynamic of how they operate to promote student development.

In this study, three sets of codes "co-occurred" frequently enough to justify a second-order analysis: *metacognition and academic self-regulation*, 46 co-occurrences; *STEM professional/science identity and interaction with faculty/staff/STEM professional(s),* 45 co-occurrences; and *STEM professional/science identity and interactions with peers*, 26 co-occurrences. Each of the texts that were co-coded were re-analyzed for ways that the co-occurring constructs might be related.

Phase I Results: Code Occurrences

The frequency of code occurrence in the text excerpts helped us to determine what experiences, activities, or aspects of the learning community that participants identified as significant, important, or meaningful for their academic development and/or success. The six most frequent codes are presented here and defined based on the content of the excerpts. Samples of student narratives are provided as exemplars.

Table 3
Frequency of Code Occurrence

Code	*# Occurrences*
Academic self-regulation	119
STEM Professional/Science Identity	105
Metacognition	96
Interaction with Faculty/Staff/STEM Professional(s)	96
Interaction with Peer(s)	88
Self-Efficacy	71

The total number of code applications was 647 (inclusive of the original 12 codes) applied to 422 excerpts that were selected from119 documents.

Academic Self-Regulation

This code was applied to 119 excerpts total, which means that in 28% of all excerpts, students reflected on their ability to regulate their classroom and study behaviors. Self-regulation refers to the degree to which students are able to monitor their levels of motivation and frustration and to adjust their behavior accordingly.

Students talked about the development of their ability to take control of their learning and regulate their behavior for academic success. The following excerpts illustrate the range of student narratives coded as academic self-regulation:

> Since the semester kicked into gear and the material became harder, I had to change how I studied again. I started doing practice quizzes as well as going through my notes again and again. My group of friends and I started to gather in my room and work out problems together for our chemistry and math classes, and started to really work as a group to work out our questions. Once we started studying and working as a group, my performance in class increased significantly. Working out the problems together made the work go by faster, so we understood the material more and had more free time to do what we wanted.

> I have been much better at keeping track of homework assignments and making sure I complete everything that is assigned. One thing that really helped me achieve this was the faculty, and speakers that attended our AToMS classes. Having the extra push and motivation from others is something that has always been able to make me strive to do better for myself.

The numerous excerpts coded as *academic self-regulation* indicate that many students associated their improvement in their ability to control their learning behaviors with their LC participation. Since there is an extensive body of evidence suggesting that differences in low- and high-achieving students are closely linked to an individual's level of self-regulation (Zimmerman & Schunk, 2008), it is notable that so many excerpts included student reflection on self-monitoring behaviors for academic success.

STEM Professional/Science Identity

This code was applied to 105 excerpts, which means that 25% of the excerpts from student journal entries, essays, and interviews reflect student self-identification as a STEM student or future STEM professional. These excerpts were coded with *STEM professional/science identity* if the student discussed developing a perception of themselves, their interests, and goals as members of a community of "scientists." For example, one student wrote:

> Fitting into a community is important, especially with technical people like me. We think differently than others and it is hard to share our findings, or communicate technology to people of other disciplines unless we can work collectively in groups.

The use of "we" in the above statement indicates that the student identifies as a member of the STEM community. Other students reflected on their career goals. For example:

> [The guest speaker] was inspiring in the sense that it made me want to work harder to continue in the computer science major and achieve my goal of becoming a Web Developer.
>
> When I first came to college, and when I joined the AToMS community, I did not know where I wanted to go after I graduated from undergad. I can say now, that after two semesters with AToMS, I've found where I'd like to be in life.

Student success in STEM coursework and their selection of a STEM career is contingent on their development of a social identity as a scientist (Herrera, Hurtado, Garcia, & Gasiewski, 2012). For this reason, it is significant that so many excerpts contained a reflection on STEM identity development.

Metacognition

This code was applied when the students indicated thinking about their thinking, or an awareness or understanding of thought processes associated with learning. Metacognition is a reflective form of thinking about thought processes (Flavell, 1979, 1987) and a skill that allows students to monitor and control their cognitive processes associated with learning. As students become aware of their own thought processes, they become increasingly able to reflect on cognitive strategies and techniques. They are able to more clearly articulate how they learn and solve problems. Thus metacognition encompasses not just the ability to learn but also the ability to undertake conscious reflection regarding *how* to learn, which is what enables students to manage their own learning. Ninety-six excerpts, representing 23% of the total code applications, were coded as indicative of metacognition. Excerpt examples include:

> What I learned from ‘methodology’ (a class topic) is that it is better to not think of a problem as one gigantic problem but to think of it as a bunch of little problems. This occurs and helps me tremendously when I try to write code in my computer science classes. If I try to tackle it head on like a bull going at a gate then there will be no way that I would ever get it done. I have to break it into little parts and go through each part piece by piece until I’m done.
>
> I have also found out that I do better in an environment where things are hands on. My memory skills are not the best, so when I do hands on work, I can work my way to the solution by seeing a practical application of the knowledge.

Gregory Thomas (2012), a scholar who focuses on metacognition as it relates to science education, argues that metacognition is a central construct and can serve as a useful predictor of successful learning. Because metacognitive skills have been shown to be related to academic performance (Young & Fry, 2008; Bandura, 1993;

Pajares, 1996; Pajares & Johnson, 1994), it is important to note that some students associated enhanced metacognitive thinking with participation in the LC.

Interactions with Faculty/Staff/STEM Professional(s)

This code was applied to 96 excerpts, which means that interactions with faculty, staff, and/or STEM professionals was discussed by students in 23% of the excerpts. These excerpts referenced a meaningful interaction, for example:

> The biggest advantage I probably saw was being in a closer relationship with the professors. Like, I definitely like getting to see professors and getting to know them better than just not being in the learning community, and that's definitely helped me out as a student.

> I love that I have formed a fantastic bond with the professor. She is really supportive and is always trying to find ways to help me learn better. I like that she wants me to succeed as a college student. Encouraging, positive people are so helpful when it comes to mental health; I am so lucky to be supported in reaching my goals.

Favorable student-teacher relationships have been associated with numerous positive student outcomes including higher academic achievement and intellectual development (Pascarella & Terenzini, 2005); interest and motivation (Komarraju, Musulkin, & Bhattacharya, 2010; Zepke, Leach, & Butler, 2010); behavioral and emotional engagement (Hughes, Luo, Kwok, & Loyd, 2008) and deep-learning (Trigwell, 2005). For this reason, it is noteworthy that many AToMS/IMS participants discussed their relationships with faculty and others in the context of the learning community.

Interactions with Peers

This code was applied 88 times, which represents 21% of the excerpts. For this code, students needed to explicitly describe a social or academic engagement with another student considered a peer. For example:

> The AToMS community has been a great help so far, I have really enjoyed meeting new people that have self-determination to become better students and that have similar interests as I do. I enjoy the topics we talk about and the lectures we have because they open my eyes to the bigger picture instead of the original narrow sight image I had of simply obtaining my degree. I really am glad I am a part of this community it has exposed me to far more things than I had expected which will help me become a better rounded individual.

According to Wentzel and Watkins (2002), peers can have a profound impact on a student's academic motivation and engagement. This makes it notable that some students reflected on the peer engagement opportunities that LC participation affords. And it is also significant that social and/or academic engagement with others, including faculty, staff, STEM professionals, and peers combined, was evident in 44% of all excerpts. This supports a sociocultural perspective on learning that places social interaction at the center of teaching and learning activities.

Self-efficacy

Self-efficacy is the belief set we have about our abilities and competence to complete tasks and reach goals. This code was applied to 71, or 17% of the excerpts from student journal entries, essays, and interviews. Some students wrote about their self-efficacy in STEM courses in general, for example:

> I grew over the progression of the semester by gaining confidence where I lack it the most, and that was by not believing in myself. I changed by changing my view on how I perceive things. I developed as a STEM student because the more I gain confidence in the field, the more I believed in myself.

Others wrote about their self-efficacy for a specific academic task:

> Throughout this semester, I have grown more mature compared to last semester. I surprisingly have developed the skill of making college level presentations!

Increased self-efficacy is strongly correlated with academic success in STEM (Zuffianò, Alessandri, Gerbino, Luengo Kanacri, DiGiunta, Milioni, & Caprara, 2013; Caprara, Alessandri, & Eisenberg, 2012; Alivernini & Lucidi, 2011; Schunk & Zimmerman, 2008), which is reflected in students' comments on a growing sense of academic self-efficacy in the context of their LC participation

Phase II Results: Code Co-Occurrences

A code co-occurrence is when codes partially or completely overlap, resulting in an excerpt that has more than one code attached to it. Code co-occurrences offer starting points for second-level data analysis because they indicate connections between codes that may merit further analysis. These associations can give us clues about contextual factors and how these factors shape participant perception and experience. However, code co-occurrences only tell us part of the story. The meaning of the code connections can only be understood through re-reading the excerpts with an eye toward how they relate to each other and the context and how they help us understand the participants' experience. This also affords us the opportunity to see not just what students *associate* with the participation in an LLC but how these constructs might *function*—the dynamic of how they may operate to promote student development.

In this study, three sets of codes "co-occurred" frequently enough to justify a second-order analysis: *metacognition and academic self-regulation, 46 co-*

occurrences; STEM professional/science identity and interaction with faculty/staff/STEM professional(s), 45 co-occurrences; and *STEM professional/science identity and interactions with peers*, 26 co-occurrences.

Each of the texts that were co-coded was re-analyzed for ways that the co-occurring constructs might be related. Each of the pairs is discussed below, with sample student narratives to illustrate student associations. (Note: Some of the excerpts were tagged with other codes in addition to the two presented here. Dedoose presents all co-occurrences, not just those that co-occur exclusively.)

Metacognition and Academic Self-regulation

The codes for *metacognition* and *academic self-regulation* co-occurred in 46 of the 422 excerpts. We found that in the co-coded narratives, students described two different experiences that prompted metacognitive activity related to academic self-regulation: a perceived personal failure and interaction with others. The first two examples illustrate the idea that a perceived failure (like not doing well on a test) prompted metacognitive activity, that is, for students to reevaluate their learning strategies:

> For this chemistry exam, I studied by going back over my homework, re-reading the sections in the book and going back through my notes from the lecture. I also looked at the sections that my professor said were going to be on the exam, and did not study some of the things that he took out of the exam. My study habits changed a little this time because I want a better grade than I made on the first test. I went back through and reworked problems and mentally quizzed myself of what I thought might be on the exam. On the last exam, I did not know what the test format was like, so for this test, I did not stress about that part. I feel like my study habits this time were better than the last. I just hope my grade improves.

> The first Chemistry test I didn't do well because I didn't use my time wisely, so for the second test I did better because I practiced using my time wisely, that was the only thing that I messed me up on the exam. My studying strategies worked, I knew the material, but when it came to the word problems I took to [sic] much time on them and wasted most of my time, so I had to rush which is not good when it comes to exams. My studying consisted of going over any new material that we learned I would go over the material that night, this helped out a lot which was good. I am not the best at conversions but ever since the first exam I have been practicing a whole lot on them, so I feel like that I have done a lot better when it comes to conversion. I thought that I could use some of the strategies that I learned in high school for college, but I learned

> very quickly that in college it is a complete different ball game, I had to come up with new ways of studying.

This third example illustrates the theme of metacognition and academic self-regulation prompted by interactions with others. This student reflects on a class discussion, then evaluates her learning strategies:

> I have studied for the upcoming chemistry test as well as other tests in many different ways. Since our last discussion on Monday, I have put a lot of thought in to trying new ways to study. Unfortunately, I haven't taken that much time to study for chemistry, except for self-assessment quizzes and a two-hour study session. Although I plan on taking different steps this weekend with my peers to really help me study. We are going to take about 2 hours at a time of studying, then move on to a different subject so as not to fry our brains. This week I had a psychology test to study for, and I had to study three chapters' worth of material. I took the initiative to really take on what we discussed in class on Monday for trying out different study spots, times, and materials. I spent most of my time in the library, as I found that was the best study spot. I cannot study without blocking the external environment out with music, therefore whenever I study I listen to music as background noise. I also studied in places like my friend's rooms to see how it would affect my studying and I also studied in the hall of my dorm as well as the picnic table outside of Guilford. In one day of studying I studied anywhere from 3-7 hours altogether. I plan on studying with my peers to help motivate each other, as well as on my own because both methods work tremendously.

An analysis of the code-occurrences of *metacognition* and *academic self-regulation* appear to indicate that while these activities are related to each other, they are also prompted by other experiences: perceived personal failure and interaction with others. This is an important finding because both metacognitive thinking and academic self-regulation are important for academic success; thus, if we understand how metacognitive and self-regulative activities might be encouraged, we can better facilitate the development of these key psychosocial learning factors.

STEM Professional/Science Identity and Interaction with Faculty/Staff/ STEM Professional(s)

There were 45 co-occurrences of the codes for *STEM professional/science identity* and *interaction with faculty/staff/STEM professionals.* This makes sense if identity formation is viewed as social construction. Herrera et al. (2012) propose that STEM identity is formed relationally, in the interactions with others that offer opportunities for recognition. The idea is that identities are socially constructed and confirmed in an ongoing process that is influenced by those with whom we interact and the feedback we receive. The following student narrative, one example of the code co-occurrences, illustrates this interactionist perspective on STEM identity formation:

> I started talking to my psychology and biology teachers on a face-to-face basis, and I learned that chemistry is not what I want to do. I want to branch out into the biology and psychology fields, and my biology professor is my biggest encouragement. She has helped me out in ways that I can not thank her enough for, she has given me opportunities to branch out and find my own identity. That opportunity has helped me realize who I am and what I want to pursue.

While many students talked about how one-on-one interactions helped them form or strengthen their view of themselves as a STEM student and future professional, others offered examples of how their STEM identity was strengthened by listening to guest speakers. The following two examples illustrate:

> I've heard advice from an engineer, two pharmacists, and a nano-scientist [guest speakers]. I've gotten a lot of good advice from them about how to handle classes and my career choices. Their advice has also pushed me to stop being so lazy and start applying myself, look for internships, and put my name out there. Their advice has made me realize that if I really want to get a job in the field I am planning on, that I'm going to have to work very hard and improve my connections with people around me and people in the field. I plan to follow their advice and have already begun looking for internships.

> I feel more certain of my academic future now after listening to the speakers. It's reassuring to hear a successful person say "Hey, I almost flunked out of my major because of math." What I mean about that is that everyone I meet and ask about the math/science courses are always like "Oh it's pretty easy" and that's it. You hardly ever hear someone say they genuinely struggled with something, and seeing that they succeeded in the long run lets me know that I definitely can succeed as well.

The excerpts that were co-coded *STEM professional/science identity* and *interaction with faculty/staff/STEM professionals* reflect that both one-on-one interactions as well as STEM-related presentations were catalysts for STEM identity development.

STEM Professional/Science Identity and Interactions with Peers

This third set of co-occurrences, *STEM professional/science identity* and *interactions with peers*, is also related to STEM identity and interaction, but with a focus on the social interactions with peers, rather than STEM faculty and STEM professionals. The 26 co-occurrences of these two codes indicate that STEM identity may be mediated by general peer interactions as well as interactions with those perceived as mentors. For example:

> My fellow AToMS students, along with IMS students, have showed me who I want to really be in school: a good student.

> The good thing about AToMS is the friendships I've formed and that we help each other with study habits, homework and lab reports. It is helpful to see familiar faces every day to make the transition from high school easier…. I feel like the community is helpful when it comes to study sessions and making connections with other STEM majors.

The examples that follow focus on the interaction with a student mentor:

> I like the fact that the AToMS students are provided with a student mentor. I feel like that is really helpful to share and discuss our future plans and the mentor can give tips and advice on which classes are good to take.

> [The upper-level student's] talk about her research experiences was very eye opening. It provided us with information about undergraduate research, which is very important for someone interested in graduate school. It gave us resources for us to take up on our own time and look into performing research in our STEM majors. It also provided us with a perspective of what could potentially be us and the challenges we would have to face if we decided to do research.

An analysis of these code co-occurrences offers ideas about how these constructs might function to promote student development. We found that students described two different experiences that prompted metacognitive activity related to academic self-regulation: a perceived personal failure and interaction with others. Regarding STEM identification, students offered examples of how both one-on-one interactions with STEM faculty and staff, as well as STEM professional guest lectures, helped them form or strengthen their view of themselves as a STEM student and future professional. In addition, students indicated that both general peer interactions as well as interactions with those perceived as mentors facilitated STEM identity as well.

Discussion

The success of STEM learning communities as mechanisms for increasing student academic performance and commitment to STEM careers prompted us to explore the underlying factors that make these communities successful interventions. As a result of our 2-year STEM learning community case study based on an analysis of 119 LC participant narratives, we offer three general conclusions and some reflections on the conceptual and theoretical frameworks they support.

First, we were able to identify four psychosocial (affect) learning factors that students said improved because of their participation in the LC: *academic self-regulation, STEM professional/science identity, metacognition, and self-efficacy*. There is a significant body of research supporting the connection between psychosocial learning factors and academic success. Pajares (2002) takes this notion further by arguing that the affect dimensions of learning are not simply factors contributing to student success, but necessary *conditions* for student academic success. If these factors are foundational to academic success, then participation in a learning community may significantly facilitate student development.

A second finding from this case study is the identification of two aspects of the LC experience that students identified as significant for their academic development*: interaction with faculty/staff/STEM professionals* and *interaction with peers*. This finding supports a sociocultural theory of learning that highlights the social forces that affect, shape, and mediate learning. Price (2005) summarizes this well: “Learning communities are the pedagogical embodiment of the belief that teaching and learning are relational processes, involving co-creating knowledge through relationships among students, between students and teachers, and through the environment in which these relationships operate” (p. 6). If this is the case, then the framework an LC provides for various types of interactions may explain why they are so successful in promoting academic success.

Finally, an analysis of the excerpts with co-occurring codes offers us clues as to the types and contexts of social interactions that students found meaningful and how they might contribute to psychosocial development.

A strength of illustrative case study research and a directed approach to content analysis is that existing theory can be supported, clarified, and extended. As we consider the results of this case study, we propose that our findings support the idea that psychosocial learning factors are developed through social interactions. If this is the case, then the social and relational opportunities provided by learning communities may be the key underlying force that explains the positive effects of student participation.

As we endeavor to increase the percentage of US college students who earn degrees in STEM fields and to address the gender and ethnic disparities in these fields, we need to better understand the factors that influence student academic achievement in STEM. Our learning community case study suggests that the development of psychosocial learning factors through social interaction may help us understand why STEM learning communities work and offers a productive direction for future research.

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