Peer Knowledge Sharing Outside the Undergraduate STEM Classroom

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Abstract

Student interest is associated with persistence in STEM courses of study (Maltese, Melki, & Wiebke, 2014). If peers decide, of their own accord, to discuss knowledge among each other outside of the classroom context, the behavior is indicative of deepening interest in the information being shared (Renninger & Hidi, 2002). Understanding outside classroom knowledge sharing behaviors among peers involved in a STEM course may help educators construct learning contexts that promote interest and persistence in STEM subjects. To that end, this study examined two important research questions: (1) what are the key factors that influence peer to peer knowledge sharing outside the classroom? and (2) what are the methods the student use to share content knowledge? In order to explore these questions, a qualitative study was designed to explore knowledge sharing between peers outside the classroom. A semi-structured interview protocol with eight students from a Mid-Atlantic community college was conducted to explore students' perceptions of knowledge sharing between peers. Data were coded and analyzed by a group of researchers and themes were identified and theoretical and practical implications of the study were recorded. Several key facilitators of knowledge sharing were identified: self-efficacy, interpersonal relationships, interpersonal similarity and media richness. Implications for teachers are presented. Limitations and future research are included in the end of the study.

Introduction

The United States (US) continues to focus on advancing K-20 STEM education in order to improve economic growth, innovation, and national security (National Science Board, 2016). In order to support the above referenced goal, the community college has taken a place of prominence in the higher education arena. The American Association of Community Colleges reports that in 2015, 41% of all US undergraduates were found in community colleges (NCES, 2017). Of all undergraduates who completed a 4-year degree in 2016, 49% had enrolled in a community college for a part of their coursework (Community College Enrollment and Completion, 2017). Interestingly, almost one-half of all undergraduates are currently in community colleges. However only 14% of those who declare as STEM majors actually persist in their

course of study as compared to a STEM persistence rate of 43% of their 4-year counterparts (NAE & NRC, 2014). These low persistence rates point to a need to improve the impact of STEM education in the community college arena.

Demographically, white students comprise 48% of the community college student population, 23% are Hispanic, 13% are African American, and 56% are women (NCES, 2017). To put this in perspective, 56% of the Native American, 52% Hispanic and 43% African American undergraduate students are found in US community colleges (College Board, 2016). Additionally, over 60% of these students require remediation in order to begin enrolling in undergraduate level courses, and overall there is a higher number of students per faculty member at public community colleges than at public 4-year undergraduate institutions (McFarland, et al., 2017).

Regardless of the educational level, meaningful educational reform begins at the level of the teachers (Darling-Hammond, 2000, 2002; Wells, 2008). Community college faculty, in particular, lack pedagogical training or understanding of the diverse, underprepared population of students that they face. These faculty are largely part-time and the vast majority of these teachers are tasked exclusively with teaching as opposed to research or a combination of the two (Provasnik & Planty, 2008). Community college classrooms, especially in STEM subjects, are characterized by more lectures and less use of research-based, constructivist, active learning techniques that are associated with significant learning, especially by women and underrepresented minorities (Hyde & Gess-Newsome, 2000; Liu & Grotzer, 2009). The 2-year faculty are largely uninformed as to what works for underrepresented minorities and women in the classroom and "tend to rely on anecdotal or impressionistic information" rather than what research tells us (NAE & NRC, 2012, p. 17). Four-year faculty view community college coursework with suspicion and a corresponding lack of confidence (NAE & NRC, 2012).

In general, in postsecondary study, "the classroom *per se* does not dominate the locus for instruction and learning to the degree that it does in K-12 settings" (Coppola & Krajcik, 2013, p. 631). Therefore, learning opportunities and discourses outside of the classroom setting are perhaps more important for knowledge sharing between peers, as a common approach to peer learning. Sharing opportunities could occur either in classroom under the teacher's instruction or outside the classroom proper. Previous research has examined knowledge sharing among peers in different settings, such as online (Eryilmaz *et al*., 2013) and in the classroom (Nemanich, Banks & Vera, 2009). However, there are several research gaps in the literature. First, most of these studies are quantitative (e.g. Eryilmaz *et al*., 2013; Nemanich *et al*., 2009). Although large scale quantitative data could have a good generalizability, they cannot aid in gaining in-depth understandings of the subject of interest (Eisenhardt & Graebner, 2007). Quantitative data may help to examine some factors related to knowledge sharing, but they cannot reveal students' thoughts and perceptions about knowledge sharing. Second, prior studies of knowledge sharing did not systematically discuss the antecedents, processes and outcomes of knowledge sharing. For example, Eryilmaz *et al*. (2013) highlighted the impact of communication media. The current study provides a more comprehensive understanding on *why* students share knowledge with peers and *when* and *how* the knowledge is shared. Finally, many previous studies discussed knowledge sharing in class among both students and teacher (e.g., Coolahan, Fantuzzo & Mendez, 2000; Boyle & Nicol, 2003; Nemanich *et al*., 2009). This study explores knowledge sharing between peers in a novel but important context: outside the classroom.

In order to explore the aforementioned gap in research, a semi-structured interview protocol with eight students from a Mid-Atlantic community college was conducted to explore

students' perceptions of knowledge sharing between peers with special attention paid to these occurrences outside of the classroom. Data were coded and analyzed by a group of researchers, themes were identified and theoretical and practical implications of the study were recorded. The interview data collected demonstrated how students actually perceive knowledge sharing outside the classroom setting and illuminated classroom factors that promote such behavior. The purpose of this preliminary study was to explore the conditions that community college undergraduate students describe as fostering peer to peer content knowledge sharing outside of their science, technology, engineering or math (STEM) classroom.

Literature Review

Peer learning is a term that refers to a learning activity in which reciprocity is made between two or more participants and may be applied to a wide variety of educational situations and learning strategies. "Peer learning should be mutually beneficial and involve the sharing of knowledge, ideas and experience between the participants" (Boud, Cohen, & Sampson, 2001, p. 3). Thus, learning from one or more peers, across disciplines, is a desirable outcome for instructors to strive toward since "partners generally engage with academic issues at a deeper level than if working alone. The support generated through this peer relationship is an important factor for academic development. Learning partnerships are characterized by openness and active discussion of ideas and processes and provide relevant experience for continuing professional development" (Sampson & Cohen, 2001, p. 39). Peer learning is an educational innovation that can transform students' learning experiences (Blumenfeld, Marx, Soloway, & Krajcik, 1996).

Peer knowledge sharing does not happen between every student under every condition. In some cases, students might seek help from peers when they are struggling or do not understand information presented by the instructor. However, some students cannot conduct this help-seeking behavior effectively (Karabenick, 1998). Blumenfeld *et al*. (1996) suggested that students might not know how to ask questions in peer group or might remain silent or withdraw to prevent looking incompetent. In addition, students are conditioned to a traditional lecture-style classroom culture which must change if deep and meaningful learning will occur. The meaningful interactions (professor-student as well as student-student) improve the likelihood of revoicing and construction of the central themes and facts and the internalization of the key points (O'Conner & Michaels, 2007). Because there are many barriers that makes peer learning and interaction inefficient, in this study, we explored the factors that influence students' knowledge sharing between peers. In our study, peers are defined as people who are in the student's class or are in a different section of the same course. Knowledge is defined as things a student learns in a specific course. Knowledge sharing refers to a situation when students discuss course content-related knowledge with their peers, solve problems jointly and/or share tips and experiences related to the things students learnt in the course.

A review of knowledge sharing and peer learning literature revealed several factors that influence the effectiveness of knowledge sharing and learning. First, a student's self-efficacy plays an important role in influencing an individual's knowledge sharing. Self-efficacy is a form of self-evaluation that influences decisions about what behaviors to undertake and the amount of effort and persistence to put forth when faced with obstacles. According to the social cognitive theory (Bandura, 1986), the perceived self-efficacy has a significant impact on individuals' motivation and behavior (Ajzen, 2002). People who have high self-efficacy will be more likely to perform related behavior than those with low self-efficacy. More recently, several studies discuss the relationship between self-efficacy and knowledge sharing (e.g. Cabrera, Collins, & Salgado, 2006; Bock & Kim, 2002). People with high self-efficacy will have an expectation of positive outcomes of a behavior. As a result, they will be more likely to execute the behavior than people who doubt

their capability. This is an important issue in knowledge sharing because the knowledge sharing process is complex and as we mentioned, there are many cognitive barriers and knowledge sharing may be construed as self-efficacy deficits. Social cognitive theory contends that the desire to share knowledge is not sufficient to carry it out. In order to share knowledge, the knowledge sender must also have the perceived capabilities to complete it (Cabrera, et al., 2006). These capabilities include authoring knowledge content, contributing personal knowledge to the team knowledge base, sharing personal knowledge in formal interaction with or across teams, or in informal interactions among individuals (Bock & Kim, 2002; Kankanhalli, Tan & Wei, 2005).

Person-object theory augments the peer sharing literature by suggesting reasons why students would share outside of class, and therefore outside of the direct influence of the teacher. Students who are interested or deepening an interest in the subject at hand will choose to interact with that subject in some way outside of original context that stimulated the interest (Hidi & Renninger, 2006). Deepened student interest is a propelling force in student motivation and thereby persistence in a field of study (Kahu, Nelson, & Picton, 2017). In the context of STEM fields, interest has been shown to be a necessary piece toward retaining students in the STEM pipeline (Maltese, Melki, & Wiebke, 2014).

Media richness theory categorizes communication media in terms of the "richness" of the media (Daft & Lengel, 1986). Richer media were "those with a greater language variety (the ability to convey natural language rather than just numeric information), a greater multiplicity of cues (the number of ways in which information could be communicated such as the tone of voice), a greater personalization (ability to personalize the message), and more rapid feedback" (Dennis & Valacich, 1999, p1). Prior studies found that richer media (e.g. face-to-face) facilitates knowledge share more than low-richness media (e.g. email) (Choi, Lee & Yoo, 2010). In today's technologically dependent society, technology, especially interactive software, social network sites, and pocket e-devices (e.g. smart phone), provides both soft and hard foundations to support collaboration among peers (Wong, Kwan & Leung, 2011). However, communications on these medias are still with low media richness (Kaplan & Haenlein, 2011). Thus, we are interested in how they influence knowledge sharing as an alternative of face-to-face interactions.

Prior studies also found that interpersonal relationship plays a critical role in knowledge sharing. Social network theory implies that the strength and the content of social ties determine how people share knowledge. First, it was found that relationships that have affective and expressive component transfer knowledge better than other types of relationships (Zhou, Siu & Wang, 2010). An effective channel of knowledge transfer is an expressive tie, which is informal, attach more emotional content, and mainly provide friendship and social support (Ibarra, 1992). For example, friendship is typically an expressive tie and loads social support and trustworthiness. Sias and Cahill (1998) found that friendship enables co-workers to discuss sensitive issues. Jehn and Shah (1997) argued that friendship enhances cooperation and open communication. In addition to the content of social ties, tie strength (the closeness of two actors) also has a positive relationship with knowledge sharing. Strong ties facilitate knowledge share better than weak ties, especially when the knowledge is tacit (Hansen, 1999).

Finally, knowledge sharing is influenced by the degree of similarity between peers. Interpersonal similarity and team diversity has a significant impact on knowledge sharing. Kearney, Gebert, & Voelpel (2009) found that age and education diversity has a positive relationship with team performance. Rulke & Galaskiewicz (2000) and Wong (2008) found that groups with larger expertise diversity will outperform groups with less expertise diversity. S. Horwitz and I. Horwitz (2007) found a positive relationship between task-related

diversity (functional backgrounds and education) and team performance. Hambrick, Cho and Chen (1996) contended that the net effect of diversity on management team performance is positive.

Although several studies support the positive relationship between dissimilarity and knowledge sharing, other studies found that dissimilarity also lead to problems and ineffectiveness. In a review paper, Jackson, Joshi and Erhardt (2003) argued that the effect of gender and age diversity on team performance is mixed. S. Horwitz and I. Horwitz (2007)'s meta-analysis research also found no significant relationship between demographic diversity and performance. Lovelace, Shapiro, Weingart (2001) found that functional diversity has a negative effect on team innovation. Tiwana and Mclean (2003) found that expertise heterogeneity negatively influences creativity. To explain the negative relationship between diversity and knowledge sharing, some research points out that although diversity leads to non-redundant information exchanges, it fails to provide enough social support (e.g. trust and shared understanding), therefore increasing intra-team conflict and difficulties in understanding (Pelled, 1996; Bechky, 2003).

Although a large number of studies have discussed the factors influencing knowledge sharing, we expect our study make new contributions because the uniqueness of the context of our study. The context of this study was in the post-secondary, community college science classroom. This learning environment is traditionally characterized by instructors who are experts in content area, but who have little to no pedagogical training (Provasnik, & Planty, 2008). The classroom is dominated by didactic instruction and laboratory work is generally limited to "cookbook" style exercises that have predicted outcomes and cultivate few STEM habits of mind such as quantitative thinking, interdisciplinary, distributed thinking, systems thinking, mechanistic thinking (Liu & Grotzer, 2009).

In order to engage students effectively in the practice of science and therefore the cultivation of the aforementioned skills, "opportunities for conversation (dynamic exchange of ideas and reflection), critical discourse (accentuating connections between ideas and evidence), and argumentation (use of evidence to process and learn about ideas)" should be provided in the classroom (Huff & Bybee, 2013, p. 30). Meaningful science learning occurs when contextualization of scientific knowledge occurs outside of the original classroom presentation and is correctly and meaningfully assimilated into the student's current learning construct. The phenomenon of shared learning within the context of the science classroom is represented in the literature. Studies that explore the effectiveness of learning communities, peer evaluation, and peer assisted learning are plentiful and explore different characteristics of learning between peers and the things that an educator can do to promote these experiences (see Palloff & Pratt, 1999). However, our understanding on the conditions *outside* of the community college classroom which exist at the time when knowledge sharing occurs between peers is still insufficient.

Methods

Participant Characteristics

Prospective participants were self-identified as students majoring in a science curriculum and had taken at least one college science course within the last five years, who are at least eighteen years old and are enrolled as either full or part time students at a "Mid-Atlantic" Community College. This purposeful sampling was used to gather information from students that had a background in rigorous college science courses with the intent to gather information from experienced students focused on obtaining a degree. Table 1 contains the participants' demographic information.

Name (pseudonym)	Age	Gender	Ethnicity	# of STEM courses taken	Major
Emery	19-20	F	Caucasian	1-3	N/A
Erin	23-24	F	Caucasian	>9	N/A
Jesse	23-24	F	Caucasian	4-6	Science
Joshua	>28	M	Caucasian	4-6	Engineering
Kelsea	23-24	F	Caucasian	4-6	N/A
Setsu	23-24	F	Caucasian	4-6	Science
Taylor	19-20	M	Caucasian	1-3	Nursing
Tanner	19-20	M	Caucasian	1-3	Science

Table 1 Interview participant demographics and educational background.

This study was conducted on the campus of a Mid-Atlantic community college in a small /mid-sized urban area. Of the approximately 12,000 enrolled, the student population is 54% female and 46% male with a racial makeup of 86% white, 9% African American and 5% other races. The average age of the community college student is 29 and 66% of the students attend part-time, on average. The unique blend of non-traditional (adult) and traditional learners contribute to a wide diversity of student need and background and perfectly situate these learners to benefit from social learning, since the diversity of backgrounds and ages provide unique opportunities outside the classroom in which to construct meaningful, lasting understandings.

Data Collection

Data were collected using two primary methods. The participants were asked to complete a brief questionnaire, which had demographic questions such as age gender, number of science classes completed, etc. Then the participants were questioned using a single semi-structured interview in which the eight participants answered a standard set of questions. See Table 2 for a concise alignment of questions with research questions. Refer to Appendix A for exact interview questions. The semi structured nature allowed the researchers to ask follow-up questions to clarify responses.

The interviews all took place on two dates separated by three days and lasted approximately twenty to thirty five minutes each. Participants were assured of their confidentiality and anonymity and a signed consent was requested and procured from each participant prior to the start of the interview. The researchers and study were reviewed and approved through all governing IRB offices. Questions were asked concerning the different methods used to exchange knowledge about academic topics with peers and their perceived effectiveness. There are four researchers and each conducted two interviews. A list of the interview questions and the demographic questionnaire are in appendix. All researchers maintained an audit trail and field notes to help document the study process. The interviews were audio recorded and then transcribed verbatim by the interviewer. Each transcription was checked by another researcher to insure accuracy. Discrepancies were reviewed and the consensuses of the two researchers were recorded to help insure the accuracy of transcription.

The participants were e-mailed after the interview to see if they had any follow up information about the interview questions. This additional information underwent the same data analysis process as the interview transcription.

Research Questions	Interview Questions (Found in Appendix A)
RQ#1: What are the key factors that influence peer knowledge sharing outside the classroom?	1, 2, 4, 5, 6, 7
RQ#2: What are the methods that students share content knowledge outside of the classroom?	1, 3, 7

Table 2 Research questions in relation to interview questions.

Data Analysis

The data were analyzed using the constant comparative method was used as described by Merriam and Associates (2002) and initially outlined by Glaser and Strauss (1967). Every interviewer reviewed each transcript once without comment which provided all members with a framework from which to judge the meaning of the participants comments (Creswell, 2007). The researchers then proceeded to analyze and code each part of the assigned transcripts that pertained to the research questions. Similar sections within a transcript were compared and the codes and concepts were then compared across the other transcripts to create a consistent set of codes for each researcher. The team members then met and compared coding and analysis and discussed coding strategy to ensure that each member had unified ideas for the basis of each code. The discussions about coding lead to the initial development of several themes and subthemes among the researchers. Each researcher was assigned five transcripts [two of their own and one from each other researcher] and this distribution assured that each transcript was reviewed by at least three researchers. The members then recoded each assigned paper based on the unified understanding of each code and general themes developed (see table 3). The researchers then met to discuss and create consensus about the themes and subthemes. A consensus of results and implications was then reached and recorded.

Findings

Analysis of the transcripts revealed several themes about the peer to peer knowledge sharing. Media richness refers to the fact that the students wanted instant feedback in their communications and information beyond textual data. Self-efficacy had a large part in the participant's willingness to share classroom knowledge. Those with higher subject self-efficacy shared more freely than those participants with lower subject efficacy. Students share course content knowledge to under the concepts better and to reinforce the ideas through revoicing the materials to others. The study indicated the participants would share more readily with peers with which they had a prior connection. This is a personal connection through another class or through a social affiliation. Participants stated that other students with highly self-centered or opinionated personalities were a very negative factor in their willingness to share knowledge.

Media richness

Students in this study overwhelmingly preferred talking face to face over written electronic communication. When they have the chance to see each other face-to-face, the sharing occurs as a part of natural social behaviors. When they go to class, they talk with classmates before and after class or when they go to the house sit around with housemates.

"I think it's pretty much talking... none of us have really ever Email to each other. Yes, mainly just talking outside the class." (Setsu)

RQ#1: What are the key factors that influence peer knowledge sharing outside the classroom?	RQ#2: What are the methods that students share content knowledge outside of the classroom?		
THIRD ITERATION: IMPLICATIONS			
Theme #5 Implications: What can teacher do to support/initiate peer knowledge sharing outside/inside the classroom?			
SECOND ITERATION: PATTERN VARIABLES			
Theme #1: Why	*Theme #2: Discouraging*	*Theme #3: Encouraging*	*Theme #4: How*
W1. Self-focus: understanding, test preparation, homework, and memorizing W2. Others-focus: help, connections	D1. Not Confident D2. Relational Difficulty D3. Competing Focus	E1. Confidence E2. Similarity E3. Relevance E4. Excitement	H1. Mode: talking vs. texting H2. Format: small group, large group, and pair
FIRST ITERATION: INITIAL CODES/SURFACE CONTENT ANALYSIS			
W1. Understanding (deeper level, same level as others, grasp the concept) W1. Performance (test preparation, homework, good grades) W1. Applicable (correlated to real life and work) W1. Learn from peers W2. Reciprocity W2. Reteach/explain	D1. Not confident with material D2. Personality D2. Attitude of receiver D3. Leaves class right afterward	E1. Confident with material E2. People with similar interest E2. People who also want to learn E2. People with similar background E3. People with some connections E4. Enthusiasm for topic	H1. Talking H1. Texting H2. Group H2. Small group H2. Pair

Table 3 Code mapping.

"So, by discussing with people about it, you not only know how you see the concept but how they relate to that concept. It give me a more comprehensive understanding." (Joshua)

"I was studying for a test so really I was trying to speak it out It goes back probably to my mind and that may make my mind keep that information." (Tanner)

The face-to-face approach was the common way of content information conversation and it was preferred by students when available.

Subject self-efficacy

Students are encouraged to share if they are confident in their own knowledge and therefore have a higher subject self-efficacy. High self-efficacy students tend to benefit from knowledge sharing through re-teaching and low self-efficacy students demonstrate more passive behaviors in knowledge sharing process. They offer less information.

"[I] want to understand, does it make sense? And then retain it again… you know, it might even give you a confident... How much you know the material might you know give you all that… OK. So, you think it would help you feel more confident... Encourage." (Tanner)

*"I feel like for people that have weaknesses, you know…even to myself, if I have very weak understanding on something, I may be less likely to say anything." (Tanner**)***

Learning objectives

Students share with peers to gain understanding and clarity of the classroom material and this is done through revoicing the material to peers or to family and friends. This can be a method to help gain subject efficacy. Several participants voiced that they shared classroom concepts with non-peers [non students] in order to gain a better understanding on the classroom concepts.

"...added part of one It (talking) helps me understand it if I'm explaining it because I can work through it in my mind." (Jesse)

"Yes, I like re-teaching it, so I can better understand it. And If I don't understand." (Erin)

"It makes me feel more confident about the knowledge and share more in future." (Joshua)

Students also share knowledge with peer to get satisfied performance in assignments or examinations.

Students also learned new strategies through exam preparation with peers.

"Usually when I were studying for test or something." (Setsu)

"I can encourage them getting better grades and they can help me with better grades." (Taylor)

"She actually gave me her flash cards." (Setsu)

Social relationships

Participants tended to share with people who have strong or prior connection. Students were more comfortable sharing content knowledge with peers that they could anticipate a level of support for their efforts.

"I don't go to people that I don't know. Absolutely people that I have some sort of connection with. Like my housemates, like my people in class." (Erin)

Interpersonal relationships

Participants were more likely to share knowledge with people of similar topic interests or level of understanding. The shared excitement about a specific class or topic was also a factor that contributed in a very positive manner to peer to peer knowledge sharing.

"… from that common interest, I am trying to understand the material, I feel like, you get more interpersonal conversation in the group." (Josh)

"…if we have other people in there that are not as focused we wouldn't accomplish half of what we need to learn, we wouldn't get through class…" (Taylor)

"I think a lot of time for me I just tend to choose people who are a little bit older. In my experience being in "Mid-Atlantic CC", I tend to… I think a lot of time because they are a little bit more motivated," (Joshua)

Participants would share classroom knowledge with students that had differing interests or levels on knowledge but this was not as prevalent as sharing with students with similar level of topic interest.

"I don't mind people disagree with me. I like people to disagree with me, because, again, like I just said, it is so hard to see…especially so often when you dealing people in class, so disagreement is a constructive disagreement." (Joshua)

Students mentioned several specific incidences of low levels of interest or perceived personality traits that would prohibit sharing or knowledge. Most participants stated that it was a person's level of excitement about a topic that encouraged them to interact with the other student. A highly opinionated or abrasive personality was an absolute discouragement to any sort of interaction.

"... I don't talk to super arrogant people who think they are right all the time when I can prove them wrong" (Emery)

"He definitely had an opinion and your opinion wasn't the same, you were gone [laugh] ...and he would say "I already knew the answer"..., I don't think we click." (Taylor)

Discussion and Implications

This exploratory study sought to shed understanding to the phenomenon of peer-to-peer knowledge sharing outside of the STEM classroom, since prior studies have determined that for undergraduates, learning outside the class is more significant than learning inside the classroom (Coppola & Krajcik, 2013, p. 631).

Overwhelmingly, community college students prefer face to face, verbal discussions in which to actively construct understandings of classroom material. These results are in support of the ideas expressed by Ford and Wargo (2012) whereby a dialogue is needed as an essential part of understanding, not just to support understanding as an outcome. However, the study revealed that seeking new knowledge was not the focus of these exchanges. Rather, revoicing what they have learned in class in a different context is what students identify as meaningful and effective in deepening their knowledge. Students specifically valued sharing opportunities in small groups and with their professor. The community college is the perfect place to support these preferences with the small class sizes and ready access to professors whose primary job is to teach.

Factors which positively influence knowledge sharing, as identified by students, were revealed to be strong science self-efficacy, heterogeneity in student age, amount of knowledge, subject enthusiasm (by students and professors), learning enthusiasm, relevance of content, and similarity of purpose. Several students said they preferred to share learning with students who were older than themselves, thus capitalizing on the heterogeneity characteristic of the community college learning environment. These results show that the dissimilarity has both positive and negative effects on knowledge sharing, providing a direct support of the findings articulated by Kearney, Gebert, & Voelpel (2009). However, community colleges are faced

with a unique challenge of educating students who have been historically unsuccessful in school as evidenced by the high number of students who must take remedial classes upon entry (Levin & Calcagno, 2008). The prevalence of students with high academic and science self-efficacy from the start is predicted to be lower than in four-year institutions, as evidenced by the low persistence rate of community college students (Fike & Fike, 2008).

Factors which were revealed as barriers to sharing were competing interests, relational difficulties, and lack of subject self-efficacy. Community college students, in particular, may be affected by the competing interest factor since the large majority of these students are part time. Community college campuses are also commuter. Thus, the students are spread so thin that the time to be involved in the learning process is limited. Students therefore identify appreciation of time directly before or after class as necessary to facilitate sharing:

"… because the things we are doing in the class is on my mind and it's a good time, because everybody is going to be there…..And sometimes just after class, you know, there is something I didn't get in class, sometimes I seek out somebody else's perspective to…errr….get a better understanding." (Joshua)

Interview data from a study performed by Bickerstaff, Barragan, & Rucks-Ahidiana (2012) with over 100 community college students revealed that student confidence continually changes as a result of interactions with peers, faculty, and others. Interestingly, a pattern of confidence was revealed by our data. Students who actively sought out peer-to-peer learning opportunities outside of class exhibited a higher level of science self-efficacy than those who did not. In addition, the students who were less efficacious reported a hesitancy to share with others, unless sought out by someone in the class. Those that were less efficacious also tended to seek out older students with which to share. Additionally, students who expressed a high level of content self-efficacy in one STEM area may not necessarily mean that that efficacy extends to other STEM area:

I: See that is what I am asking. So you felt good about sharing in physics but not the same in anatomy. Can you put your finger on why?

S: 'Cause in physics it was a mathematical approach more. There was a lot more math involved in that physics class and I can explain math. (Jesse)

Thus, it is clear that subject efficacy is a dominating factor in knowledge sharing and STEM disciplines are not created equal in this regard, despite the fact that they support the same set of general literacy skills. See Figure 1 and 2 for a diagrammatic representation of the key factors which were revealed to be important in peer-to-peer knowledge sharing.

Implications for undergraduate STEM instructors

The influence of the teachers on students' academic self-efficacy has been well established (Pajares, 1996). The results of our study revealed specific conditions which influence students' knowledge sharing outside of the classroom and therefore point to specific ways that educators may extend this influence to outside of the classroom.

Construction of specific situations to promote sharing. Professors should provide frequent, structured in-class opportunities for students to share knowledge with each other in small groups. For example, the "think-pair-share" or other such cooperative activity may be the perfect opportunity to begin the sharing process. In particular, students believed that starting and ending the class time with meaningful sharing opportunities would be beneficial. These moments may capitalize on the excitement of learning new information and sow the seeds of relevance and connection that students clearly articulate as essential. In order

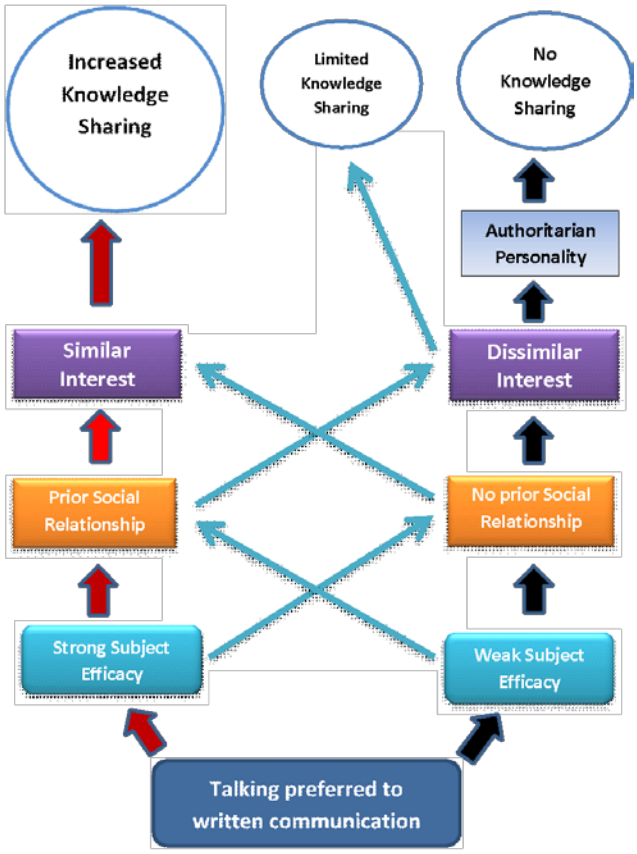

Figure 1 The knowledge sharing process

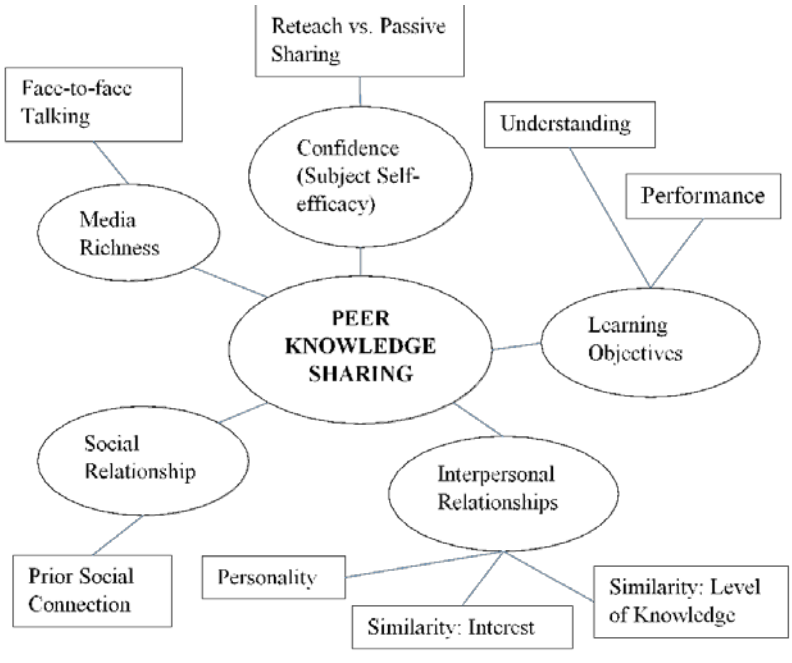

Figure 2 Concept map of themes, outcomes, and their connections.

to improve the likelihood of students' interactions with each other outside of class, the teacher should make both random and deliberate small group assignments throughout the semester, being sure to distribute people with different sharing and subject efficacies.

Assignments should be created to continue discussion outside class. In order for all students, but specifically students with low academic and/or science self-efficacy, to have opportunities for interaction without the structure of the classroom and direct oversight of the instructor, the course must be purposely designed with this outcome in mind. Examples of this kind of planned opportunities for outside discussion may be: 1) to share content knowledge with a family or friend (perhaps in the form of an interview) and then report back to the class on relevant findings, 2) seek ways to connect assignments to the outside world in both content and practice of science, or 3) use video technologies such as SKYPE or Blackboard's Illuminate to require students to continue voice interactions outside of class. Additionally, using such technologies for additional out of class interaction with the professor may also be of benefit, such as a consistent recitation opportunity with small groups of students.

Intentional construction of assignments to improve subject efficacy, not just content knowledge. In keeping with the vast amount of literature that ties academic achievement and persistence with academic self-efficacy (Pajares, 1996), professors should intentionally seek to understand student academic and content self-efficacy at the outset of the course and seek to construct opportunities for improving academic confidence throughout the semester.

Community college professor professional development should include training in effective course construction and how to promote knowledge sharing inside and outside classrooms. In order to teach at community college, professors are not required to have any pedagogical training. As a result, according to Colbeck, Campbell & Bjorklund (2000), higher education faculty are not prepared to manage student groups or structure meaningful group activities. In addition, the National Research Council (1999) reports that "existing school practices are inconsistent with what is known about effective learning". Thus, instructors should be deliberately schooled in effective teaching and learning techniques to positively impact learning behaviours exhibited by students, such as knowledge sharing.

Effective STEM courses should be integrative and not occur in disciplinary isolation. Students who are confident in one STEM subject no not necessarily exhibit confidence in other STEM disciplines. In addition, students look for opportunities to construct knowledge in contexts outside of class. By intentionally teaching the content and practice of each STEM discipline in concert, students will be given greater opportunity to find ways to connect learning to real life and construct new meanings outside of the classroom. Finally, STEM habits of mind, such as those identified by Pines (2009) - solving problems using both mathematics and science, focusing on problems, imagining solutions, demonstrating persistence through obstacles, using effective oral and written communication, and working in either teams or alone- are supported by meaningful conversations outside of class.

Limitations of Research

The research methods used were a single interview protocol which necessarily limits the depth of the information received and allowed no follow-up questions to seek additional clarity. The age and ethnicity of some of the researchers were markedly different from the participants but a review of the transcripts and field notes did not reveal any references or possible impacts based on these differences.

The reader cannot infer that students outside this study will be influenced by the same factors mentioned in this article. The participants in this study were in a two year college pursuing a science or science related major, and many

other factors influence the amount of peer to peer knowledge sharing.

All the participants volunteered to be interviewed and this demonstrated a certain level of extrovertedness and possibility a preference to verbal communication compared to written communication.

Future Research

Our study results can inform future research in several ways. Our research mainly focused on the factors that facilitate the students to initiate conversations with peers. Students used the sharing opportunities to construct new understandings. However, how to influence students in the move from newly constructed understandings into seeking new knowledge to add to their construct would be a meaningful extension to this present study. What factors are necessary to encourage students to question and extend their knowledge?

Building on the self-efficacy literature (Bandura, 1986; Bock & Kim, 2002), our study shows that students' self-efficacy plays a significant role in knowledge sharing. However, the role of the teachers' self-efficacy is not well examined in our study. Previous studies have demonstrated that teachers' teaching self-efficacy is critical for student learning (Tschannen-Moran & Hoy, 2001; Zee & Koomen, 2016). Further research should explore the role of teachers' teaching self-efficacy and its influence on student peer-to-peer knowledge sharing.

Finally, our research focused on only face-to-face STEM students. Therefore, revealing the factors which influence peer-to-peer knowledge sharing in online STEM learners should also be undertaken. Student who self-select into online courses may have different perceptions of communication modes and different motivations to share outside of their perceived classroom learning, since all formal learning experiences are virtual.

Conclusion

This study was an exploratory investigation to understand peer-to-peer knowledge sharing outside of the undergraduate STEM classroom. Through interviewing, we sought to ascertain the factors which influence knowledge sharing and the preferred method(s) by which students exchange classroom knowledge with peers. It is the hope of the authors that some of the knowledge gathered in this study can be integrated into classroom settings by teachers to facilitate increased peer-to-peer information exchange outside of the STEM classroom setting in order to improve depth of knowledge and STEM habits of mind.

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Appendix A

Interview Questions

This study is about peer-to-peer knowledge sharing that occurs outside of the actual classroom.

For the purposes of this study, “peers” is defined as people who are in your class or are in a different section of the same course. “Knowledge” is defined as things you learn in the science course and “knowledge sharing” is when you discuss science knowledge with your peers, solve problems jointly, and/or share tips and experiences related to things you learn in science.

1. Through this study, I am looking to understand about your sharing things learned in class outside of the classroom. Would you please tell me about your experiences?

2. Why do you share with peers?

3. How do you share with peers?

4. What keeps you from sharing knowledge with peers outside of the classroom setting?

5. What encourages you to share knowledge with peers outside of the classroom setting?

6. Who do you tend to share classroom knowledge with? Do these people have any common characteristics?

7. Do you have anything else you would like to add?

Appendix B

SURVEY FOR PROJECT:
When does knowledge sharing take place between peers in an Associate's degree program?

Purpose of this Research Project:
The purpose of this preliminary study is to explore what out-of-class experiences undergraduate students describe as fostering peer to peer classroom knowledge sharing. None of the following questions is required to be answered.

TODAY'S DATE: _____

YOUR NAME: _____
EMAIL ADDRESS: _____
ARE YOU OVER 18 YEARS OLD? _____(Y/N)
WHAT IS YOUR AGE? _____
ARE YOU THE FIRST PERSON IN YOUR IMMEDIATE FAMILY TO ATTEND
COLLEGE _____(Y/N /not sure)
WHAT IS YOUR GENDER? _____
WHAT IS YOUR ETHNIC BACKGROUND?_____
WHAT IS YOUR MAJOR AT [College XXX]: _____
NUMBER OF COLLEGE LEVEL SCIENCE COURSES YOU HAVE COMPLETED: _____
ARE YOU CURRENTLY TAKING A COURSE WITH ANY OF THE RESEARCHERS? ____(Y/N)

WOULD YOU LIKE AN EMAIL COPY OF THE FINAL REPORT? ____(Y/N)

I KNOW THAT THE COMPENSATION FOR PARTICIPATION IS INCLUSION IN A RANDOM DRAWING OF ALL PARTICIPANTS FOR A $20 GIFT CARD AND RECEIVE A SLICE OF PIZZA AT THE TIME OF THE INTERVIEW. THE DRAWING WILL BE HELD WITHIN 24 HOURS AFTER ALL INTERVIEWS ARE CONCLUDED AND THE WINNER WILL BE NOTIFIED BY EMAIL. YOU ARE FREE TO WITHDRAW AT ANYTIME AND WILL RECEIVE FULL COMPENSATION.

I UNDERSTAND THAT THIS INTERVIEW WILL BE AUDIO-RECORDED AND TRANSCRIBED FOR USE IN A RESEARCH PAPER THAT MAY BE PUBLISHED. _____(INITIAL)

I ACKNOWLEDGE THE INFORMATION PROVIDED ABOVE IS TRUE.

_____ _____
Signature Date

THANK YOU VERY MUCH FOR YOU HELP WITH THIS PROJECT!!