Preservice Science Teachers' Collaborative Knowledge Building through Argumentation on Healthy Eating in a Computer Supported Collaborative Learning Environment

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ABSTRACT
The purpose of this study was to investigate preservice science teachers' collaborative knowledge building through socioscientific argumentation on healthy eating in a multiple representation-rich computer supported collaborative learning (CSCL) environment. This study was conducted with a group of preservice science teachers (n=18) enrolled in a technology in science education course at a large, high research activity university in the Southeastern United States. Data sources were the representations created by the participants in a CSCL platform across three representational modalities, audio recordings of classroom activities and posters created by the groups. To investigate learning in the collective level social network measures of density and centrality were utilized. Furthermore, content analysis and text mining were used to analyze students' representations. Reflected in the participants' wikis, individual learning was assessed using argumentation analysis rubrics and content analysis of representations and posters. Results indicated that the knowledge base created jointly with different representations by the participants was improved, the written argument contents both shared more commonalities in terms of content and shared more common words as a reflection of the participants' collective effort. In an individual level, analysis of the learners' written arguments indicated that some participants increased their argumentation qualities in their final arguments, all participants incorporated more specific scientific knowledge and aspects from other participants' arguments. It was concluded that collaborative knowledge building with multiple representations increase learning both in the individual and collective levels.

Keywords: argumentation; collaborative knowledge building; computer supported collaborative learning; science education

INTRODUCTION
In the intersection of science and social issues, socioscientific issues (SSI) have become an important research theme in science education (Sadler, 2004). Challenging life issues such as cloning, global climate change, stem cells, genetically modified organisms often emerge with the advent of science and technology and can affect multiple aspects of daily life. Therefore, these global and local issues have been used as engaging and authentic contexts for science teaching (Topçu, Yılmaz-Tüzün, & Sadler, 2011). SSI are dilemmas which include multiple perspectives and involve individuals in decision making processes. Making well-informed decisions about these complex issues require individuals to engage in evidence based reasoning and argumentation (Zeidler, Sadler, Applebaum, & Callahan, 2009). Through argumentation individuals can weigh evidence and reach a decision about these issues (e.g., Raven, Klein, & Namdar, 2016). Therefore, in science education research, identifying the mechanisms of socioscientific argumentation has become an emerging research agenda (Evagorou & Osborne, 2013).

Argumentation about SSI can be framed as a social activity in which learners "collaboratively build upon each other's knowledge, adding to the communal knowledge pool" (So, Seah, & Toh-Heng, 2010, p.480) as well as to improve their individual understanding (Scardamalia & Bereiter, 2003). One challenge for science educators is to provide environments that help students build and advance communal knowledge of these issues. Computer supported collaborative learning (CSCL) can be used as an effective medium for collaborative knowledge building for SSI. CSCL environments allow learners to co-construct knowledge with the help of computers within and across classroom settings (Stahl, Koschmann, & Suthers, 2006). CSCL supports the co-construction of knowledge with the aid of external representations (Cress & Kimmerle, 2008). As information about SSI is represented in multiple modalities and multiple formats such as in graphs, tables, text, audio, and pictures, CSCL offers a space for storing and sharing information in and across classrooms about complex SSI. The process of organizing knowledge using CSCL platforms make thinking visible and provide a space for exchanging ideas for developing new knowledge through representations (Kimmerle, Moskaliuk, & Cress, 2011; Stahl, Ludvigsen, Law, & Cress, 2014).

Research on collaborative knowledge building indicated that learners use CSCL platforms to build knowledge to argue about different subjects (Namdar, 2015; Namdar & Shen, 2016). Considerably less attention was paid to the mechanisms of socioscientific argumentation in collaborative knowledge building communities that were supported with multiple representations. Therefore, the purpose of the current study is to explore the influence of collaborative knowledge building on preservice science teachers' (PSTs) collective learning and socioscientific argumentation on healthy eating. Understanding the influence of CSCL environments on PSTs collective and individual learning is crucial to scaffold PST education, if SSI are to be used in future science classrooms to promote argumentation and scientific literacy (Kolstø, 2006; Sadler, 2004). The research addresses the following questions,
In a CSCL environment:

1. How do PSTs build collective knowledge with multiple representations on healthy eating?
2. How is collaborative knowledge building related to PSTs' individual argumentation about healthy eating?

THEORETICAL PERSPECTIVES

COLLABORATIVE KNOWLEDGE BUILDING

Science is a social enterprise and scientific knowledge advances through collaboration (National Reseach Council, 2012). In educational settings, collaborative inquiry has become an important educational goal (NGSS Leads States, 2013). This emphasis on collaborative learning rather than individual inquiry gave birth to the notion of knowledge of knowledge (Scardamalia & Bereiter, 2006). Based on this emphasis, Scardamalia and Bereiter's (2006) conception of contemporary education focused on the idea of knowledge-creating civilization. As an overarching theoretical perspective, they suggested the knowledge building theory "to refashion education in a fundamental way, so that it becomes a coherent effort to initiate students into a knowledge creating culture" (p. 97). In short, this theory stems from the idea that a community of learners jointly creates knowledge (Scardamalia & Bereiter, 1994). It assumes that, individual learning and understanding scientific concepts are byproducts of this knowledge building activity (Moskaliuk, Kimmerle, & Cress, 2009) and the Internet becomes a mediating tool between classroom and the civilization-wide knowledge building community in this process (Scardamalia & Bereiter, 2006). Overall, collaborative knowledge building can be defined as "...the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts" (Scardamalia & Bereiter, 2003, p.1370). Through collaborative knowledge building, one can be exposed to and evaluate alternative ideas brought from others' perspectives (Stahl, 2000).

CSCL environments act as scaffolds for collaborative knowledge building (Kimmerle et al., 2011). These environments incorporate representations in multiple modalities for users to build knowledge such as verbal-textual (written text, oral propositions), symbolic mathematical (i.e. formulas, equations), and visual graphical (i.e. simulations, diagrams, tables, graphs) (Wu & Puntambekar, 2012). The advantage of using multiple representations in learning can be three-fold: a) representations can either support complementary cognitive processes or include complementary information, b) one representation is used to constrain the misinterpretation of another representation, and c) representations foster deeper understanding (Ainsworth, 1999). Next, I explain how I approach collaborative knowledge building with multiple representations.

COLLABORATIVE KNOWLEDGE BUILDING THROUGH REPRESENTATIONS: A SYSTEMIC AND COGNITIVE VIEW

In this study, I adopt Cress and Kimmerle's (2008) model to describe my approach to collaborative knowledge building with external representations in CSCL environments. Cress and Kimmerle (2008) offer systemic and cognitive view on collaborative knowledge building with wikis (i.e. a type of textual external representation) by combining the systemic approach of Luhman and Piaget's theory of equilibration. Luhman's systemic approach (Luhman, 1995) distinguishes social systems from cognitive systems. Cognitive systems operate through consciousness and cognitive processes such as recalling information. Social systems, on the other hand, operate by means of communication. As social systems are dependent on cognition, cognitive and social systems influence each other (Luhman, 1995).

To explain how social and cognitive system's borders are crossed during learning, Cress and Kimmerle (2008) built their argument on two processes: externalization and internalization. According to their view, representations help learners to externalize their knowledge (e.g. in a textual representation such as a wiki). Externalization of knowledge maps and reflects an individual's cognitive processes in a representation that exist independent from the individual's cognition. During externalization individuals change, deepen, and extend their existing knowledge (Cress & Kimmerle, 2008). The internalization process occurs when an individual works with a representation and integrates information available in the wiki to their knowledge, thus extending their previous knowledge. Cress and Kimmerle (2008) further argued that through internalization people could infer new knowledge, which cannot be otherwise possible unless the information in a representation was internalized. As CSCL environments allow learners to create and share representations, people also develop new knowledge by the altering the knowledge in the representations. In return, the knowledge representation becomes an epistemic representation that exists independent from its creator (Popper, 1972; Sterelny, 2005).

Cress and Kimmerle's (2008) collaborative knowledge building approach also draws on Piaget's model of equilibration (Piaget, 1970). Equilibration explains the two processes when an individual is faced with new information and integrates it into their own knowledge: assimilation and accommodation. Assimilation is the process where an individual understands new information based on the existing prior knowledge and integrates the knowledge in their existing schema. Accommodation on the other hand, is the process in which an individual changes their existing knowledge to understand new information. In collaborative knowledge building these two processes occur both internally and externally and develops together (Luhman, 1995; Luhmann, 1986). Combining both systemic view and equilibration, in collaborative knowledge building with representations, therefore, learning and the collaborative knowledge building occurs in four ways: "a) Internal assimilation (quantitative individual learning), b) internal accommodation (qualitative individual learning), c) external assimilation (quantitative knowledge building), and d) external accommodation (qualitative knowledge building)" (Cress & Kimmerle, 2008, p113).

In this study, the learners were provided with a new CSCL platform (see technology platform section below). The platform incorporates three different representations. Different from previous studies on collaborative knowledge building, the technology the participants used visualizes connections between representation by the keywords learners assign to categorize, sort, cluster information (Namdar & Shen, 2016). In a previous study, for instance, students created representations to reflect their initial knowledge of nuclear energy (Namdar & Shen, 2016). Some learners only added different representations without adding/coediting others' representations or extending the knowledge represented in the platform. This process is an example of external assimilation. However, learners frequently created new representations in the platform to add distinct aspects of nuclear energy (e.g. radiation and cancer, nuclear energy dependency of US) and extended the knowledge base represented in the platform. Furthermore, learners coedited each other's entries and rearranged information. This revision and creating representations reflecting different aspects of a phenomena can be interpreted as external accommodation.

In the current study, collaborative knowledge building was further identified on two levels: collective and individual. In the collective level learners' externalization accommodations and assimilations contributes to a web of knowledge representations in the technology platform. Thus, representations created in the technology platform reflect collective understanding of the whole class (Figure 1). This digital artifact, in return, can influence individuals' cognitive assimilations and accommodations. In the individual level learners' build their individual knowledge reflected in a representation.

SOCIOSCIENTIFIC ARGUMENTATION

In recent years, argumentation has received much attention from the science education community (Lin, Lin, & Tsai, 2014). It is the process of constructing, evaluating or validating claims through evidence (Jiménez-Aleixandre & Erduran, 2008). In science education, Duschl and Osborne (2002) defined argumentation in two forms: rhetorical and dialogical. Rhetorical argumentation includes the linguistic aspect of argumentation when creating arguments. Toulmin's (1958) model of argumentation components includes six categories: a) *Claim* conclusions, opinions and hypothesis or assertions made about facts; b) *data*: evidence that support claim; c) *warrants:* statements, rules, or principles that connect claim and the data; d) *backings:* statements that justify warrants; e) qualifiers: conditions where there is a restriction on the claim; f) *rebuttals*: statements that rebut and defeat the warranting conclusion. Furthermore, argumentation can also be framed from a social, dialogical perspective. In a dialogical argumentation perspective, another party comprises an important place in developing multiple perspectives and constructing knowledge in the argumentation process (Andriessen, 2006; Jonassen & Kim, 2010). Dialogical argumentation occurs with the presence of another individual or the interlocutor in mind. Different from dialogical argumentation, collaborative argumentation is the social construction of knowledge in which learners work to solve a problem through sharing ideas, challenging and justifying assumptions within and among groups. In the current study, Toulmin's model was adopted to analyze changes in learners' argument structures. Additionally, collaborative argumentation has also guided this work similar to other studies in the SSI literature for two reasons. First, as SSIs involve the negotiation of issues that has multiple solutions, learners use collaborative argumentation to be exposed to distinct ideas and perspectives, as well as to weigh alternative ideas to reach well-informed decisions (Sadler & Donnelly, 2006). Second, collaborative argumentation was used in the current study to enhance knowledge base in the learning environment. This was ensured through engaging students in small group and whole class argumentation, and asking students to incorporate their arguments in a shared online platform so that their peers can be exposed to multiple arguments on different topics in the learning environment and finally can (co)construct their own understanding of healthy eating.

METHODS

A *blended mixed methods research design* was employed to *better understand* collaborative knowledge building with multiple representations (Greene, 2007). In this design, methods assessed the different aspects of collaborative knowledge building and served for the *complementarity* purpose. A complementarity mixed method study enabled me to use both quantitative and qualitative methods to analyze different facets of the phenomenon, namely collaborative knowledge building in the collective level and in the individual level (Greene, Caracelli, & Graham, 1989). Qualitative and quantitative data were collected concurrently and the status of methods had equal weights (Greene, 2007).

CONTEXT AND THE PARTICIPANTS

This study was conducted with a group of PSTs (n=18) enrolled in a technology in science education course at a large, high research activity university in the Southeastern United States in 2013-2014 fall semester. Demographically, the participants were 16 Caucasian and two Asian-American (11 female and seven male) PSTs. In the group, there were two graduate students. The class met once a week for a three-hour period at a computer lab and focused on teaching the ways to use technology. Due to missing students during the implementation, the groups had different number of students. Although all 18 PSTs who participated to study created representations in the technology platform (see below) six participants (two male and four female) were missing in the final presentation day. Even though the six participants did not do the final presentation; rest of their data were valid for use by all other participants. Therefore, we included six participants with missing representations in our analysis of collaborative knowledge building but we excluded them from the analyses regarding argumentation in the setting.

The reason for choosing a technology course to implement the current study unit was twofold. First, the literature supports the idea that PSTs are at the place to affect future students and preservice teachers' experiences during teacher education programs are fundamental. This study was aimed at familiarizing preservice teachers with a new CSCL platform so that they can consider using it in their future teaching. Second, I introduced preservice teachers to the ways to use such technologies to foster socioscientific argumentation in classrooms. During the study, each participant had a computer connected to the internet to work on and the participants were randomly assigned (Patton, 2002) to five groups (two groups of three, one group of four and one group of two students. During the semester, another instructor taught the course. To build a rapport with the participants, I attended all previous class sessions before teaching the current healthy eating unit and implemented the study towards the end of the semester.

PROCEDURES

The study was implemented in four sessions. (a) Introduction (65 minutes): In the first session, the participants were introduced to argumentation, the use of representations, and concept mapping. They were also introduced to the technology platform and used it to get familiar with it. Then, the participants were asked to write what they understand from healthy eating on a Wiki. At the end of the session, the participants were assigned to groups and asked to decide on a topic of interest. (b) Individual knowledge organization: As homework (session 2), each participant was asked to find information about a topic of interest and create one entry on each representation mode in the technology platform on the topic that their group decided. (c) Collaborative learning (135 minutes): In the third session the participants used collaboration tools in the platform and reviewed other participants' representations. They were then engaged in small group argumentation. Based on the argumentation, they revised their entries in the technology platform and created posters reflecting their groups' positions about their topic of interest. (d) Presentations (100 minutes): In the fourth session groups presented their posters. Each participant had a chance to visit other groups' posters and took notes. Finally, the participants were asked to rewrite their what they understand about healthy eating on a wiki page in the technology platform. They were also given a questionnaire with open ended questions about the use of different representations in argumentation (Namdar, 2015).

TECHNOLOGY PLATFORM (Innovative Knowledge Organization System: iKOS)

The participants used a hypertext, web-based CSCL platform that supports individual and collective learning through knowledge organization and collaborative knowledge building: innovative knowledge organization system, iKOS (http://ikos.miami.edu/). iKOS incorporates three modes of representations: textual (Wiki), pictorial (Event, since renamed PicTag), and Concept Map. Wiki is similar to the popular Wikipedia, that allows learners to create primarily textual representations. The Wiki space also allows users to insert up to three visuals next to their text. In Event, users can insert static pictures. With an annotation tool, users can tag and insert words and short phrases in their tags to highlight important parts of the picture and reflect understanding of scientific phenomena depicted in the picture. Users can also create Concept maps to show and build relationships within a set of concepts.

What is unique to iKOS is that it creates a knowledge web (Figure 1) of entries (i.e. each representation created by a user/users) based on the keywords that users assign for organizing their entries. Knowledge web is a tool that visualizes the representations that were linked in our CSCL platform. The platform creates this web of entries and users can easily move in between representations that are created on the similar topics. The links between representations were created automatically by the platform based on the keywords learners generated.

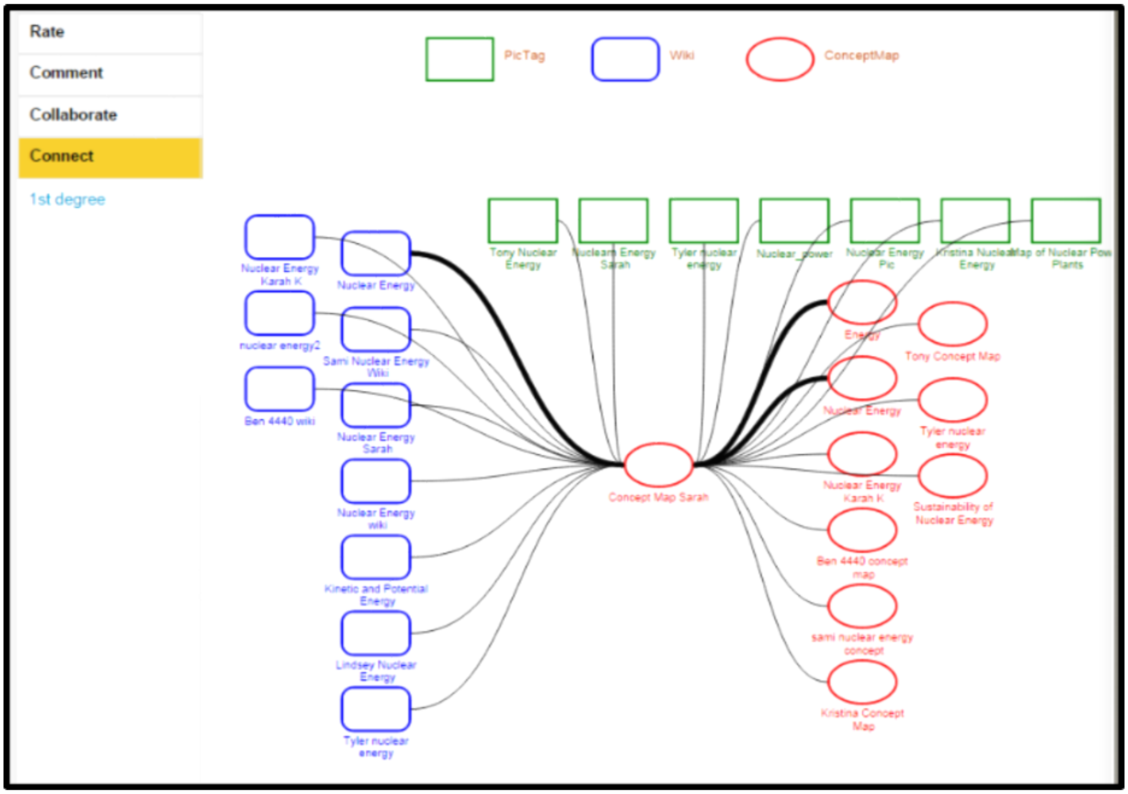

Figure 1. Knowledge Web in the iKOS

DATA COLLECTION

The participants' entries in the technology platform and their written arguments were the primary data sources and the audio recordings of the classroom interactions were the secondary data sources in this learning environment. All audio recordings were transcribed verbatim. The participants' names were changed to pseudonyms where the letters represented group names and numbers represented each participant in the group.

DATA ANALYSIS

Social network analysis measures were used to identify collaborative knowledge building reflected through the participants' representations (Knoke & Yang, 2007). First, to understand how learners build knowledge using different modalities of representations in the knowledge network, social network measure of *density*, after the first and the fourth sessions were calculated and compared. Density is a social network measure that indicates how well a knowledge base is connected. Therefore, an increase in the density indicates stronger social dynamics in the study (Hong, Chai, & Tsai, 2015) and thus it indicates how well collaborative knowledge building occurs and how dense the interaction is in the learning community. Density is calculated by dividing the total number of existing links between the participant generated representations by possible links between entries in the knowledge web (Knoke & Yang, 2007). Second, content analysis was used to analyze the participants' wiki entry content (Neuendorf, 2002). As the participants were not instructed to modify their concept map and event entries, only the changes in wikis were analyzed. Through content analysis the key phrases were identified and put into a one by one matrix. Then, if the key phrases of one participant's entry matched another participant's in the class it was identified as a connection. Based on the connections, density was calculated and the network was visualized (Figure 2). Third, *text mining* strategies were used to identify the changes in the collaborative knowledge base (Feldman & Sanger, 2006). The participants' initial arguments in their wiki entries were logged into .txt files. Using the *R* statistical package, I ran text mining analysis. During the analysis, repeated and unnecessary words were deleted from the files and the strength of connections based on the *words* used were shown in diagrams (Figure 3).

To answer the second research question, I compared participants' first and final arguments reflected in their wiki entries. First, to understand how individual learning progressed in the learning environment, we described and compared learners' written argumentation qualities (see Table 1) using Toulmin's Argument Pattern (TAP) framework (Erduran et al., 2004). Although this framework has been widely used in science education (Kaya, 2013; Kim, Anthony, & Blades, 2014; Ozdem, Ertepinar, Cakiroglu, & Erduran, 2013), it does not address the level of scientific knowledge or number of aspects used to construct arguments. Hence, to identify the changes in individual arguments, a structure of argumentation in terms of the (a) level of scientific knowledge incorporated (no mention, superficial, general, specific) and (b) the number of aspects incorporated were coded (Tal & Kedmi, 2006). The coding rubric for the level of scientific knowledge is illustrated in Table 2. The number of aspects incorporated in the arguments referred to the reasoning modes utilized to negotiate the healthy eating issue (Wu & Tsai, 2007). The aspects included different types of healthy eating option arguments, such as low fat. We counted the number of different aspects (reasoning modes) incorporated in an argument.

Table 1. TAP Analysis Rubric (Erduran et al., 2004)

Level	Explanation	Example
Level 1	Arguments that are a simple claim versus a counter-claim or a claim versus a claim.	Low fat diet is the best way of healthy eating.
Level 2	Consist of a claim versus a claim with either data, warrants, or backings but which does not possess any rebuttals.	Low fat diet is better for health because studies show that low fat diet helps losing weight and decrease the risk of heart attacks.
Level 3	Consists of a series of claims or counter-claims with either data, warrants, or backings with the occasional weak rebuttal.	Low fat diet is better for health because it decreases the hearth attach risk. It also decreases the bad cholesterol. Some people are against this type of diet but they are usually not knowledgeable about the issue.
Level 4	Arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter-claims.	Low fat diet is better for health because it decreases the hearth attack risks by lowering the bad cholesterol. Although some people say that low fat diet is dangerous due to lack of essential fatty acids, low fat diet promotes the intake of all essential fatty acids in proper amounts.
Level 5	An extended argument with more than one rebuttal	Low fat diet is better for health because it decreases the hearth attack risks by lowering the bad cholesterol. Although some people say that low fat diet is dangerous due to lack of essential fatty acids, low fat diet promotes the intake of all essential fatty acids in proper amounts. Some people also argue that low fat diet is bad for lowering cholesterol for neural impulse transfer but low fat diet controls the minimum amount of cholesterol that should be taken.

Table 2. Coding the Level of Scientific Knowledge Incorporated

Level of Scientific Knowledge	Explanation	Example
No mention	A claim is not justified by scientific concepts, principles or theories. These arguments often include intuitive responses given to the SSI or claims not supported by any data, warrants or backings.	I think eating healthy means not putting empty calories in your body.
Superficial	An argument mentions scientific concepts or scientific principles but these are not either elaborated.	I think eating healthy means eating low fat meals because it lowers bad cholesterol.
General	An argument with general scientific knowledge mentions the abstract, generalized scientific principles to justify the claim but does not elaborate on the scientific principle	I think eating healthy means eating low fat meals because it lowers bad cholesterol that is deposited into the arteries.
Specific	These arguments either references very detailed science content or has a specific science phenomena followed by elaboration to justify a claim.	I think eating healthy means eating low fat meals because it lowers cholesterol. Cholesterol is transferred in the arteries via low density lipoproteins (LDL). LDL raises cholesterol level. When the LDL levels increases high density lipoproteins decreases which takes the extra cholesterol from cells. High fat diet increases the LDL and this develop plaques in the arteries.

Second, although the participants' argumentation interactions were reflected through the text mining and social network analyses, it was not evident where exactly the participants acquired their new knowledge. To identify the source of changes in the final argument, subjects in the written arguments were identified and compared with the keywords and phrases found through content analysis of the posters and the representations. For all qualitative analysis, another expert researcher in science education coded all data as well as the author of this paper. The interrater reliability was calculated .85 for the argumentation analysis coding and .80 for the content analysis coding for posters and written arguments (Miles & Huberman, 1994). Through four cycles of peer debriefing sessions, all inconsistencies in the coding were discussed and codes were compared until the disagreements were resolved (Lincoln & Guba, 1985).

RESULTS

COLLABORATIVE KNOWLEDGE BUILDING AT THE COLLECTIVE LEVEL

Results indicated that 18 participants generated 37 Wiki, 15 Event, and 15 concept map entries in the platform. The number of links each representation had were 224 for Wiki, 105 for Event, and 224 for concept map at the end of this unit. Overall, the knowledge base created with multiple representations had the density of 0.09 and this increased to 0.13 at the end of the unit. This increase in the overall knowledge network indicates an improvement in the collaborative knowledge building through externalization. This small increase might be the result of students' limited experience with the technology platform. On the other hand, an earlier analysis of the student reflections regarding the use of the technology platform also indicated that some learners had difficulty understanding the utility of concept maps and event entries embedded in the platform (Namdar, 2015).

As the participants were explicitly instructed to revise their written arguments in the learning environment, 12 participants' (i.e. students who completed all the activities in the platform) initial and final written arguments about healthy eating were analyzed using content analysis (Neuendorf, 2002). A two-mode matrix has been generated based on the codes which emerged from the data. It was found that the density of the knowledge base increased from 0.23 to 0.53, meaning 53% of the possible links were present at the end of the intervention. Figure 2 shows the connections between learners' written arguments on healthy eating. In the figure 2 each square indicates a wiki entry created by a student and arrows indicate a relationship between two wiki entries in terms of their content. Figure 2 and the results indicate that the knowledge base reflected in wiki was increased. For instance, students A3 and C4 (Figure 2), who did not have matching ideas in their wiki entries with the rest of their peers also increased their knowledge through collaborative knowledge building by incorporating different ideas from other students.

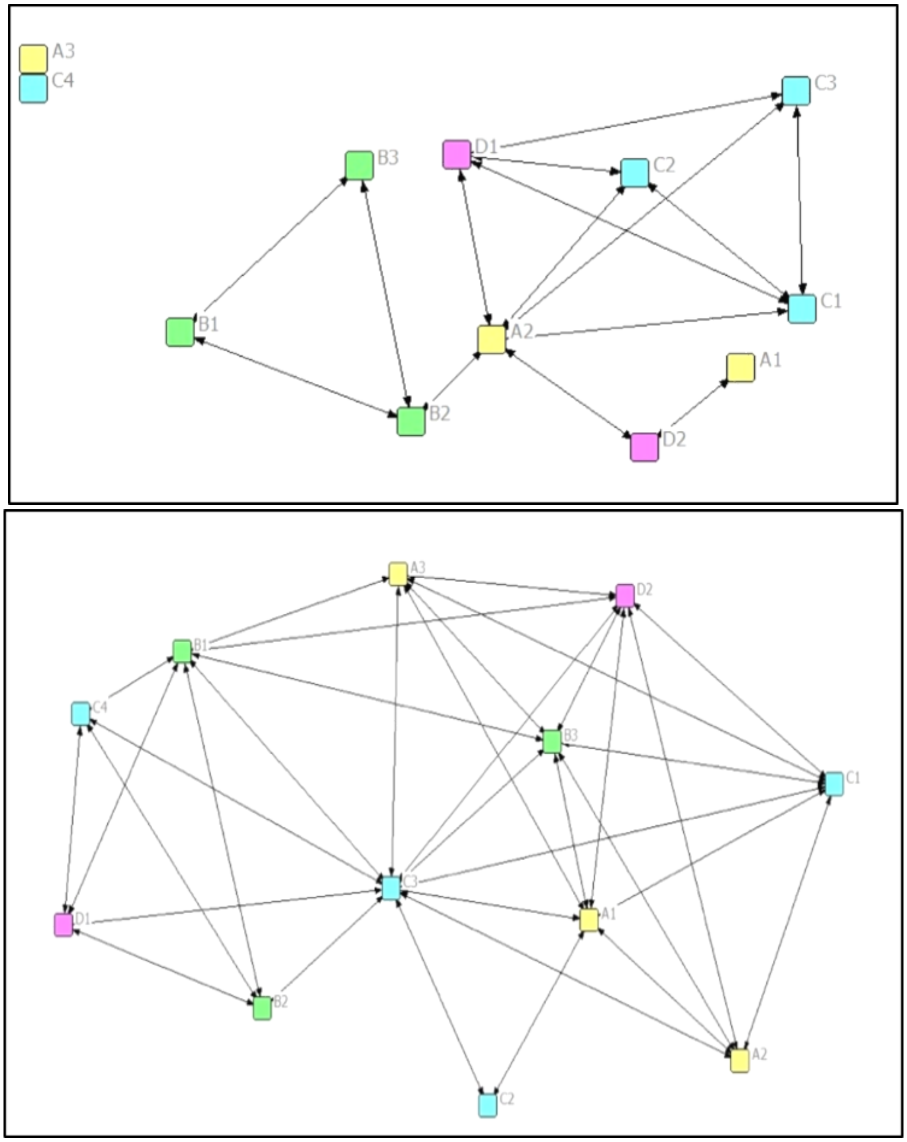

Figure 2. Connections between learners' argument contents before (top) and after (bottom) collaborative knowledge building

To look at the one mode network, learners' written arguments were analyzed using *R* statistical package. Unnecessary and repeated verbs (e.g., I, you, that, those, me, her, etc) were deleted. The bubbles in Figure 3 indicate the participants' written arguments and the diameter of each bubble shows the amount of common words that wiki entry had with the others in the network. Figure 3 reveals that after collaborative knowledge building activities on healthy eating, the participants' arguments shared more common words in their final arguments.

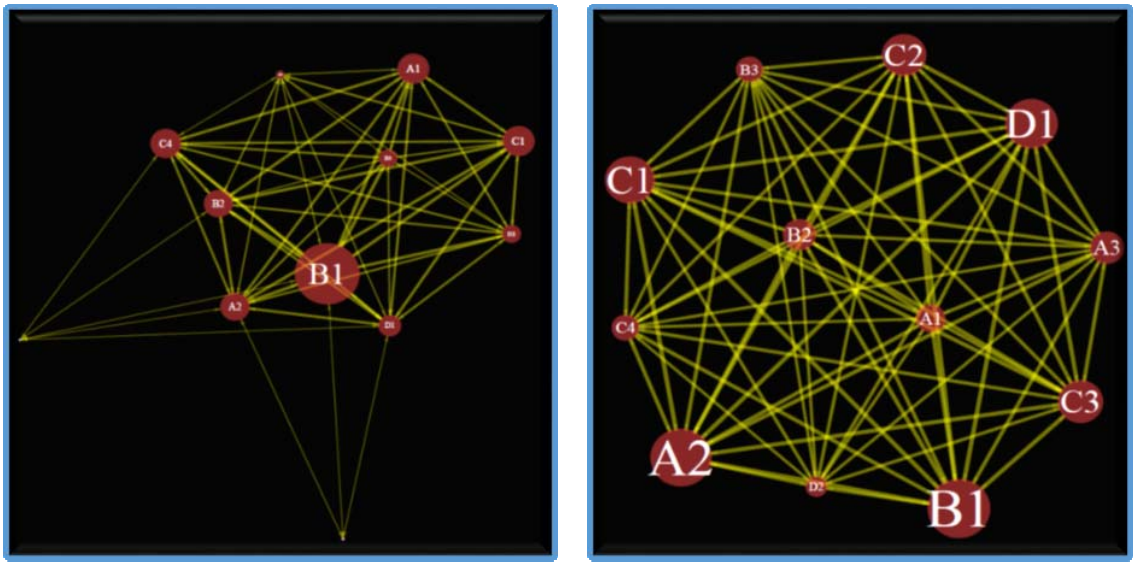

Figure 3. Amount of common words in wiki entries in learners initial (left) and final (right) arguments

COLLABORATIVE KNOWLEDGE BUILDING AND INDIVIDUAL ARGUMENTS

Written argument qualities. Results indicated that the participants' initial and final written arguments had two differences. First, utilizing the TAP (Erduran et al., 2004) framework to analyze participants' argument qualities, it was found that at the individual level, seven participants increased their argumentation quality, two participants had the same level of arguments and three participants' argumentation quality decreased (Table 3).

Table 3. Argumentation Qualities of Each Participant

Student ID	Argument Quality		Argument Structure: Scientific Knowledge		Argument Structure: Aspects Incorporated		The sources of aspects incorporated in the final argument
	Initial Arg.	Final Arg.	Initial Arg.	Final Arg.	Initial Arg.	Final Arg.	
A1	3	4	N	G	1	4	Poster presentation & representation
A2	3	4	Su	G	2	4	Poster presentation & representation
A3	1	4	N	G	1	2	Poster presentation & Initial argument
B1	3	3	Sp	Sp	3	2	Initial argument
B2	4	2	G	Sp	1	2	Poster presentation & representation
B3	4	2	Su	Su	1	3	Initial argument
C1	2	5	Su	Sp	2	1	Initial argument
C2	1	5	N	G	1	5	Poster presentation & Initial argument
C3	1	4	N	Sp	1	3	Poster presentation & representation
C4	1	3	N	G	1	1	Poster presentation
D1	2	2	G	G	3	1	Representation
D2	2	2	G	Sp	1	3	Poster presentation & Initial argument

N: No mention, Su: Superficial, G: General, Sp: Specific

Written argument structures. Utilizing argumentation analysis tools, it was found that the participants' arguments on healthy eating after collaborative knowledge building changed in two domains: (a) use of scientific knowledge and (b) aspects incorporated. Through investigation of the participants' use of scientific knowledge in their written arguments I found that ten participants increased their use of scientific knowledge while one participants' scientific knowledge incorporation remained the same and the other participant already had specific use of scientific knowledge in her initial and final arguments. For instance, in her initial argument C4 only incorporated claims while not supporting it by providing justifications which is a level 1 argument.

> Eating healthy means taking care of your body. Although eating healthy is not necessary for normal body functioning, it does increase the productivity of the body system. If we want our bodies to function to the best of their ability, we must input the best food that we can to fuel the functions that the body carries our daily routine (C4, initial wiki entry).

It is evident from this argument that there is no incorporation of justifications as in the form of specific scientific knowledge. The student however, indicated that her views changed based on the unit, especially on a gluten free diet.

> My opinion did change on the issue of gluten free vs gluten enriched diets. *Celiac disease causes gluten intolerance and leads some people to not digest gluten.* With the rise of gluten free options in many stores and restaurants, it seems that there is a spike in the number of people believing that they have celiac disease. In fact, only 1 % of the population has been diagnosed with celiac disease making it seem as though the popularization (C4, final wiki entry).

On the other hand, collaborative knowledge building helped some of the participants to see different aspects of healthy eating. Initially most participants (n=8) argued their position from one aspect associated with the issue. Aspects included ideas and knowledge about genetically modified organisms, gluten free diet, vegetarian diet, low calorie, low fat diet and sport and exercise. Only four participants used multiple aspects of healthy eating subject to construct arguments. After the intervention, it was found that eight participants incorporated more aspects, three students who initially used multiple aspects decreased the number of aspect incorporated, and one participant constructed their argument using only one aspect. However, increased incorporation of aspects did not always indicate increased quality of scientific knowledge used in the argumentation. For example, B3 increased the aspects incorporated in his argument from one to three but scientific knowledge used remained as superficial in his written arguments. B3 in his initial argument mentioned that

> Gluten allergies are all the rage in today's society. With the actual percentage of American's with Celiac disease at about 1%, why are so many people switching to a gluten-free diet? Many argue that the pros of a gluten-free diet offer a healthier diet. Actually, a gluten-free diet can rob you of many essential nutrients. A gluten-free diet has become more of a gluten-free lifestyle, and it is about time gluten started fighting back (B3, initial wiki entry).

On the other hand, B3's final argument included aspects of moderation, hazardous materials on food, and exercise but did not include any identifiable rebuttals.

> There is no one secret to eating healthy and living a healthy lifestyle. You must contribute a number of things into your daily life in order to ensure that your daily nutrition is being met without unhealthy excess. One common theme that I observed is moderation. You can eat most things, even the gluten devil, and still eat healthy as long as it is in moderation. Also, it is important to remember that some normally healthy foods, may be tainted with genetic hormones, pesticides, and other health hazardous materials. Exercise and diet are the key to living a healthy lifestyle. Quick diet fixes or extreme weightlifting alone will not make you a healthier person. It takes effort to live a healthy lifestyle, but the pros definitely outweigh the cons (B3, final wiki entry).

Similarly, a decrease in the aspects incorporated did not necessarily indicate a decrease in scientific knowledge quality. C1 for instance in her initial argument incorporated two aspects associated with healthy eating: calorie intake and eating vitamin-mineral rich foods. However, her initial argument did not include counter claims or identifiable rebuttals. In her final argument, she had a level 5 argument which included identifiable arguments but only included one aspect of the issue without incorporating ideas from others in the class.

> With proper planning, vegetarians can be as healthy, if not healthier, than non-vegetarians. A plant-based diet is linked with cardiovascular health, reduced risk diabetes and some types of cancer prevention. However, maintaining a balanced diet as a vegetarian takes work. Just like non-vegetarians, vegetarians are susceptible to the allure of refined sugars and fats. Additionally, one can argue that most plants do not contain all the essential amino-acids necessary for the body to make proteins. However, vegetarians vary the types of protein rich-foods they eat to include some legumes (beans, nuts, and soy) and some whole grains and seeds (cereals, breads, rice etc.). Additionally, one can also argue that they are vulnerable to certain types of nutrient deficiencies--which can be remedied by eating a well-balanced diet. In order to stay healthy, a vegetarian must consider the amount of calcium, iron, and other nutrients he or she is eating on a daily basis. In light of the research, it seems that vegetarians that

> are willing to put in the work to maintain a balanced diet are probably healthier than the rest of us (C1, final wiki entry).

The sources of aspects incorporated. Regarding the aspects incorporated in the final written arguments, eight students incorporated ideas presented during the final presentations. Additionally, five students also incorporated ideas that other students included in their representations. There were six students who also incorporated their initial ideas in their final written wikis.

> Eating healthy means a *balanced level of calories for your activity level*, [drawn from the initial wiki] age, gender, and health concerns, and should include a moderate level of meats, vegetables, gluten, as well as exercise to keep your metabolism up. *GMO's even have a place in our society as the foods produced can yield foods with higher nutritional content and give our society to keep up with our ever-increasing population demands* [drawn from the poster presentation of Group A] (D2, final wiki entry).

For instance, D2 in his final argument incorporated one aspect from his initial wiki and another aspect that was emerged from a poster presentation.

DISCUSSION

In summary, the participants in this study were provided with a CSCL platform that incorporates three different modalities of representations and were asked to organize and build knowledge collaboratively on healthy eating. Results indicated that the knowledge base created jointly by the participants were improved and the written argument content both shared more commonalities in terms of content and shared more common words as a reflection of a collective effort through wikis. On an individual level, analysis of learners' written arguments indicated that some participants increased their argumentation qualities in their final arguments, most participants increased scientific knowledge use, and incorporated more aspects in their arguments.

CSCL environments provide learners with tools and representational modalities to support intersubjective knowledge creation and creation of group artifacts (Stahl et al., 2014). Argumentation-based CSCL environments known as ABCSCL offer knowledge representation tools to support argumentation (Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2012). Although these representational tools are provided in the forms of schemas, visualizations, and scripts and tables, in this study learners were provided with a hypertext platform including distinct representational modalities. In particular, what was unique to our platform was that it generated a web of knowledge based on learners' representations in the platform. The results of this study suggest that providing students with different representational tools in an argumentation setting enhances group products. Although the increase in the connectedness of the network through three representational modalities was small, there was an important increase in the connectedness of textual representations. Therefore, as an implication I suggest providing students with multiple representational modalities in a CSCL environment to foster group products and teaching the purposes and uses of visual representations to better support argumentation.

Collaborative knowledge building studies often identify collaboration in wikis through content analysis (Lin & Reigeluth, 2016) and log file analysis (Kimmerle et al., 2011). Different from the literature, I used distinct and multiple methodological approaches to identify collaborative knowledge building reflected in learners' wikis. I used namely, text mining, content analysis and density measures to identify collaboration in wiki representations. Text mining strategies and density measures together indicated the collaboration degrees in the learning environment. These approaches also allowed me to identify students with isolated ideas and how collaborative knowledge building activities allowed them to incorporate ideas from different learners. As an implication, CSCL researchers could combine social network analysis techniques such as text mining and density along with content analysis to show collaboration in the network.

Despite the variety of instructional tools in CSCL settings such as shared work spaces, gaming environments and knowledge representations, learners may have difficulties arguing in these environments either face to face or online (Noroozi et al., 2012). The results of the current study showed ature that some participants had either the same or decreased argumentation qualities. This might be the result of design of the iKOS platform as well as the design of the learning unit. Literature suggests that providing highly structured collaboration scripts in these CSCL environments may increase students' learning outcomes during complex collaborative problem solving activities (Beers, Boshuizen, Kirschner, & Gijselaers, 2005). Therefore, researchers may provide structured scripts to enhance argumentation qualities and thus individual learning.

SSI-based curricula have been criticized because it could degrade the integrity of science (DeBoer, 1991). However, recent empirical studies have shown that SSI-based curricula can increase students' scientific content knowledge (Dori, Tal, & Tsaushu, 2003; Klosterman & Sadler, 2010; Zohar & Nemet, 2002). Furthermore, SSI-based curricula interventions increase students' scientific knowledge incorporations in arguments (Tal & Kedmi, 2006). In this study, on an individual level, learners who had distinct ideas in their wiki entries (A3, C4, see figure 2) incorporated more specific scientific knowledge on healthy eating in their argumentation at the end of collaborative knowledge building activities. All but one participant increased their level of specific scientific knowledge incorporation in their arguments. Therefore, SSI-based argumentation interventions should provide learners with opportunities for collaborative knowledge building so that the learners can interact with their peers and adopt scientific knowledge to use in their arguments.

CSCL classrooms present different challenges for monitoring argumentation, as much of the discourse occurs face to face and were also mediated by the information embedded in co-created digital artifacts in technology platforms (Philip, 2010). Therefore, there is a call for combining different methodologies to understand complex interactions in collaborative environments because students work both in collaborative groups and individually (Jeong, Hmelo-Silver, & Yu, 2014). To understand collaborative knowledge building on healthy eating, I used mixed methods research and benefited from social network measures, argumentation, and content analysis. I provided empirical evidence on the use of social network techniques to visualize and describe relationships between digital artifacts to identify collective learning (de Laat, Lally, Lipponen, & Simons, 2007). As there is a call for combining different methodologies for investigating individual and collective learning (Jeong et al., 2014), I used a common coding and counting approach to understand the differences in individual learning (Chi, 1997). By implication, I suggest that CSCL researchers use multiple methodologies to investigate learning at the individual and collective levels and to reach deeper understanding of their relationship (Greene, Benjamin, & Goodyear, 2001). This can be established through utilizing multiple data sources and analysis techniques (Smith, 2006; Teddlie & Tashakkori, 2003).

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This study serves as an initial attempt to identify collaborative knowledge building's effect on students' socioscientific argumentation. Although multiple data sources were presented in the study, the technology platform did not tell us which student visited which representation and for how long. Future design of such CSCL platforms might log this information to show possible links between time spent to study a representation and using this information in argumentation. In the study, the participants' in class interactions were not video recorded. Therefore, the amount of time each participant spent, for instance, listening to poster presentations or reading other groups' posters were not identified. This might have influenced students' written argumentation. Hence, future studies should also pay attention to the amount of time spend in verbal discourse and students' physical actions should also be studied to identify the underlying mechanisms of collaborative knowledge building. The current study was also limited by the small number of participants and the representational modalities that the platform was able to offer. Therefore, results should be interpreted cautiously.

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