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Exploring the collaborative synthesis of information during online reading

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ABSTRACT

This descriptive study sought to understand the complexities of integrative processing during collaborative online reading. Student pairs constructed a collaborative understanding while reading online information about a controversial issue by connecting, combining and organizing information that originated from prior knowledge, self-selected online texts, and discussions during an online inquiry task. Thirty-eight students from an upper secondary school in Finland worked in pairs to read online information and write an essay with the help of an argument graph tool. Primary data sources consisted of: prior knowledge; discussions; notes recorded with a graphic representational tool; video capture files of online use; and essays. The following results emerged: 1) a methodology and a taxonomic system were developed for the study of information sources involved in collaborative synthesis; 2) the integration of ideas from multiple online texts was difficult for adolescent students; 3) students with better essays used more online information whereas students with less remarkable essays relied more on prior knowledge that was activated during online reading. The methodology used in this study provides initial direction for research on the complexities of synthesis during collaborative online reading, an increasingly important aspect of learning in schools. Limitations and future directions for research are discussed.

1. Introduction

The ability to collaboratively learn from online information is important for today's knowledge work (Organization for Economic Cooperation and Development [OECD], 2010). An essential aspect of learning from online information is the ability to integrate (Wiley et al., 2009), or synthesize (Leu, Kinzer, Coiro, Castek, & Henry, 2013), ideas from multiple online texts. This is where ideas are synthesized, meaning is constructed, and learning takes place. Synthesizing ideas from multiple online texts leads to a better understanding of issues compared to relying on a single text (Britt & Rouet, 2012; Wiley & Voss, 1999) and it also serves the learning of new knowledge that is neither explicitly stated nor implied in texts (DeSchryver, 2015).

Most of the work on synthesizing, or integrating, information from multiple texts has been conducted with a limited amount of texts and with individual readers (Barzilai & Strømsø, 2018; Barzilai, Zohar, & Mor-Hagani, 2018). We know relatively little about how it takes place online, with unlimited resources and among multiple readers. Nor do we know much about how synthesis takes place during initial stages of collaborative online reading, as student pairs gather information from multiple resources, or later aspects of synthesis, when student pairs collaborate on communicating their understanding in a joint essay. While we recognize that synthesis is likely to be more complex than a simple, two-stage model might represent, the distinction between initial and later aspects of this process is useful for capturing a preliminary understanding of what might later be studied in greater complexity. Understanding learning in these more complex contexts would support instructional research now taking place in today's connected classrooms (Barzilai et al., 2018) and help prepare students for the new learning demands required by online information. In this study, we explore an approach that enables us to better understand how students synthesize different sources of information, at two points in time, during collaborative online reading that include: multiple online texts; prior knowledge; discussion; and new ideas that appear during the collaborative writing of what was learned. The approach developed in this study and the results that were obtained may provide direction for additional studies into the complexities of how we collaboratively learn from online information and support the development of new instructional models in connected classrooms. We review four areas below that are related to this investigation.

1.1. Theoretical perspectives related to the synthesis of information from multiple texts

Synthesis, or the integration of meaning from multiple texts, is

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included in several theoretical frameworks concerned with reading to learn in complex text environments reviewed by Barzilai et al. (2018): Historical Thinking Strategies (Wineburg, 1991), Multiple-Document Task Based Relevance Assessment and Content Extraction (Rouet & Britt, 2011), New Literacies of Online Research and Comprehension (Leu et al., 2013) and Internet Information Problem Solving (Brand-Gruwel, Wopereis, & Vermetten, 2005). Barzilai et al. (2018) found three key aspects that were common in all four frameworks. First, all frameworks emphasized the role of connecting, combining, and organizing information from multiple texts for learning. Second, integration or synthesizing includes several, often iterative processes that include: task interpretation, text selection and evaluation, and processing individual texts. Third, integration or synthesizing involves creation of a task product that can be realized in varying forms, such as a new text product or a solution to a problem. On the basis of these commonalities, Barzilai et al. (2018) defined the integration of multiple texts as "connecting, combining or organizing information from different texts to achieve diverse aims such as meaning-making, problem-solving, or creating new texts" (p. 4).

Two of the aforementioned frameworks, New Literacies of Online Research and Comprehension (Leu et al., 2013) and Internet Information Problem Solving (Brand-Gruwel et al., 2005) have emerged from the additional demands that the Internet presents for reading comprehension and problem solving. Both perspectives informed this investigation, especially the former. The New Literacies of Online Research and Comprehension (Leu et al., 2013) defines reading online as a self-directed text construction process in an unrestricted and networked information space that involves several intertwined practices: forming questions, searching for relevant information, evaluating online texts, synthesizing information from multiple online texts as well as communicating what one has learned. Synthesizing information on the Internet may include building connections across different text types, texts with various purposes, and texts utilizing various modes of communication, such as textual information, audio, visuals, and moving images (Hartman, Hagerman, & Leu, 2018).

Obviously, building a coherent representation across multiple online texts is more complex compared to building a representation of a single text, as multiple, online texts are more likely to contain both conflicting and complementary information (Goldman & Scardamalia, 2013; Strømsø, Bråten, & Britt, 2010; Wiley et al., 2009). Further, readers need to attend to additional source information (Brante & Strømsø, 2018; Rouet & Britt, 2011; Wineburg, 1991) and account for differences among purpose, bias, and credibility of sources (Barzilai & Zohar, 2012). Accordingly, Cho and Afflerbach (2017) suggests that online reading involves building a coherent representation of text information as well as a coherent representation of intertextual connections. This idea was supported by a recent study (Kiili et al., 2018), showing that identifying main ideas from a single online text and synthesizing information across multiple texts required different skills even though these two skill areas were correlated.

1.2. Prior knowledge and the synthesis of information from multiple texts

An additional aspect to be considered when exploring the synthesis of multiple online texts is prior knowledge. It is well-established that the prior knowledge readers bring to texts is important during the reading of single texts (Kintsch, 1998; McNamara & Kintsch, 1996) and multiple texts (Bråten, Anmarkrud, Brandmo, & Strømsø, 2014; Bråten, Ferguson, Anmarkrud, & Strømsø, 2013; LeBigot & Rouet, 2007). Information stated in texts is often insufficient for the construction of a coherent mental representation, requiring the contribution of a reader's prior knowledge (Kintsch, 2004). Given the importance of prior knowledge during the reading of single texts, prior knowledge is likely to be even more important during multiple text comprehension because readers need to make inferences across multiple texts written by multiple authors for multiple purposes (Barzilai & Strømsø, 2018). Strømsø et al. (2010), for example, found that students' prior knowledge facilitated both their intratextual and intertextual understanding of multiple offline texts. Additional work is required to also understand the intricacies of how this process takes place when students engage in co-constructing knowledge from multiple online texts.

1.3. Collaborative synthesis of information from multiple texts

Research on reading to integrate or synthesize information from either multiple offline or online texts has mainly examined individual reading processes (Anmarkrud, Bråten, & Strømsø, 2014; Cho, Woodward, Li, & Barlow, 2017; Coiro & Dobler, 2007). This has been the case even though collaborative learning situations, where two or more learners co-construct knowledge through discussions, are often beneficial (Chen, Wang, Kirschner, & Tsai, 2018; Lou, Abrami, & d'Apollonia, 2001). A recent meta-analysis indicated that learners engaging in collaborative learning in computer-supported settings reached better knowledge achievement and skill acquisition (e.g., argumentation skills, critical thinking skills) than those who worked individually (Chen et al., 2018). There are several mechanisms that may explain the beneficial effects of collaborative learning. Interaction with peers provides opportunities for students to make their thinking explicit, negotiate different perspectives, and build, extend and monitor one another's understanding (Dillenbourg, 1999; Teasley, 1995).

In spite of the emphasis on reading as an individual practice, recent research (Castek, Coiro, Guzniczak, & Bradshaw, 2012; Kiili, Laurinen, Marttunen, & Leu, 2012; Passig & Maidel-Kravetsky, 2016) has also began to draw attention to reading as a social practice that includes multiple participants and mediation by cultural tools (Klein & Boscolo, 2016). Initial evidence suggests that online synthesis and learning may be enhanced when students engage in productive collaboration (Castek et al., 2012; Kiili et al., 2012; Passig & Maidel-Kravetsky, 2016). For example, Knight and Mercer's (2017) observations highlighted the importance of the quality of epistemic talk while three small groups of 11- to 12-year-old students searched for information in relation to both closed and open questions about role models.

In this study, we investigated how student pairs synthesized information during a collaborative online research task and how they communicated their understanding in a joint essay. For the purpose of this study, we expanded the definition of integrating multiple texts used by Barzilai et al. (2018) to also include prior knowledge and students' discussions during online research and comprehension. Thus, in this study *collaborative synthesis of online texts is defined as building a new, joint text product by connecting, combining and organizing information that originates from prior knowledge, self-selected online texts, and discussions in which at least two readers engage during online research and comprehension*. Building a collaborative synthesis with multiple sources of information, especially on a controversial issue, is a challenging task. Often, graphic representational tools are used in classrooms to scaffold students' thinking in complex, meaning making tasks such as this.

1.4. Representational tools for supporting the collaborative synthesis of multiple texts

Online research about controversial issues often requires argumentative reading from multiple texts. Argumentative reading refers to identifying supporting arguments and counter-arguments from texts as well as evaluation of these arguments (cf. Newell, Beach, Smith, & VanDerHeide, 2011). This can be supported with graphic representational tools (Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2012; Scheuer, Loll, Pinkwart, & McLaren, 2010) that provide opportunities to make relations between arguments more explicit (Suthers, 2001), represent the structure of the arguments (Scheuer, McLaren, Weinberger, & Niebuhr, 2014), consider multiple perspectives of a topic (Suthers & Hundhausen, 2003), and monitor progress on the task (Veerman, Andriessen, & Kanselaar, 2002). Argument graphs can also support

students' source-based argumentative writing as they help students to reorganize pieces of information (Cox, 1999) and to include supporting arguments and counter-arguments in their essays (Chryssafidou, 2014).

Representational tools may be particularly helpful in collaborative learning situations where they serve as a common ground and shared focus, and facilitate discussions (Chen et al., 2018; Scheuer et al., 2014). A meta-analysis (Chen et al., 2018), including 16 studies that used visual representational tools to support collaborative learning, indicated that representational tools supported both knowledge acquisition and social interactions as well significantly improved group performance (e.g., essays, problems solutions, or other artefacts). In spite of these positive results, the effects of representational tools may vary depending on tasks, topics and circumstances. For example, van Drie, van Boxtel, Jaspers, and Kanselaar (2005) did not find a facilitative effect of representation tool on the quality of students' historical reasoning in the essays nor learning outcomes measured in the posttest. This study included the use of a graphic representational tool, an argument graph, to support students' analysis of multiple online texts and argumentative discussions about a controversial issue.

2. Purpose of the study

The purpose of this descriptive study was to explore the collaborative synthesis of ideas at two points in time: during initial and later periods of online reading. Previous work on multiple text comprehension has not yet considered the combination of these more complex, important, and facilitative contexts for reading, often found in today's classrooms. Thus, we also needed to develop an approach that would allow us to capture and analyze the multiple sources of information that contributed to understanding of a controversial issue, including prior knowledge. Our focus was on describing the collaborative synthesis of ideas as students read and learned from multiple online texts.

The following three questions were addressed:

1) How did student pairs synthesize information while they engaged in the initial aspects of collaborative online reading for gathering information from multiple resources with an argument graph tool for preparing an essay?
2) How did student pairs synthesize information while they engaged in the later aspects of collaborative online reading for communicating the achieved understanding in a joint essay?
3) How did student pairs, who produced different levels of essay quality, synthesize information in the initial and later aspects of collaborative online reading?

3. Method

3.1. Participants

Thirty-eight students (ranging from 16 to 18 years of age, 24 females and 14 males) from an upper secondary school in the 7th largest city of Finland volunteered to participate in the study. The study was integrated into the language arts course “Text and influence.” The aim of this course is for students to learn how texts and language are used for persuasion. Students also learn how to analyze and produce different types of argumentative texts. Thus, before the study, participating students were taught the basics of argumentation.

Following this, students formed pairs to complete the activities in the study. Students were invited to self-select partners so they would feel more comfortable in sharing their ideas together (see Dirks, 1999; Kreijens, Kirschner, & Jochems, 2003). As a result of the self-selection process ten girl-girl pairs, five boy-boy pairs, and four girl-boy pairs were formed.

3.2. Introducing students to the argument graph

In this study, students' collaborative synthesis of online information about a controversial topic was supported with a representational tool called DREW (Dialogical Reasoning Educational Webtool) that was designed to support students' argumentative activities (Corbel, Girardot, & Jaillon, 2002). This tool was selected because it is easy to use, and it has been successfully used in promoting and analyzing debates (e.g., Lund, Molinari, Séjourné, & Baker, 2007; Salminen, Marttunen, & Laurinen, 2010).

The web-based argument graph that allowed students to perform several functions: 1) write arguments in boxes; 2) draw links showing the connections between the arguments in each box; and 3) label the links between each argument as either supportive of one another (+), critical of one another (−), or neutral (?). This resulted in an argument graph that indicated a set of arguments and the relationships between these arguments. An example of an argument graph from one student pair is presented in Appendix A.

Before beginning, the student pairs participated in a 10-minute training task. During the training sessions, each student pair and the researcher explored together arguments for and against the increased use of nuclear power. They formed argument boxes, links, and labels with the tool to represent that information. The session ended when students confirmed that they understood how to complete all elements of the argument graph.

3.3. Task and procedure

Following training, student pairs were asked to write an argumentative essay on the issue “Should Internet censorship be tightened?” According to the writing practices in Finnish language arts classes, the essay was a form referred to as a deliberation essay. In a deliberation essay, considering different perspectives and weighting arguments are more important than taking a certain position (an opinion essay). In line with this practice, students were directed to search for information on the open Web without any restrictions and consider arguments both for and against censorship. The task assignment is presented in Appendix B. The student pairs worked in three phases:

1. *A prior knowledge activation phase:* The student pairs were asked to discuss the topic and construct an argument graph on the basis of their prior knowledge (10–15 min).
2. *An online reading phase:* The student pairs were asked to search for and read additional information on the Web and to modify their argument graph based on their online reading (30 min).
3. *A writing phase:* The student pairs composed a joint essay by utilizing the information in their argument graph (45 min).

The researcher sat in the same room as each student pair, in succession, completed the sequence of activities and thus, was available in case students had any questions or needed help in solving technical problems. Throughout the task, the students worked together on two computers. One computer was used for recording information on the argument graph during the prior knowledge activation phase and the online reading phase. The argument graph on this computer was then used as a resource to inform the writing phase. A second computer was available to search for and read information on the Web during the online reading phase and for writing the essay with a word processor during the writing phase. A software program was used to capture, as video files, the discussions and all of the students' web-based activities on the computer screen. Discussions were transcribed.

3.4. Data collection and sources

Data collection was organized by the three phases of the task: prior knowledge activation, online reading, and writing. During each phase

of the task both product and process data were collected. Generally, product data consisted of what students wrote during each phase. Process data consisted of verbal protocols from discussions that were collected during each of the three phases using an interaction approach (cf. Miyake, 1986). An interaction approach uses pairs, or groups of participants who are instructed to talk together as they perform a given task, similar to a think aloud protocol (Pressley & Afflerbach, 1995). Product data was our primary data source, and process data was used to aid our interpretations.

During the prior knowledge activation phase, information in the argument boxes of each argument graph and the links between boxes were used as product data to represent students' prior knowledge. Verbal protocols were used as process data to interpret students' argument graphs and also to capture ideas from prior knowledge that were activated during this phase but did not appear in students' argument graphs.

During the online reading phase, new additions to the argument graph were used as product data to represent ideas that resulted from students' online reading. Verbal protocols, supplemented by video files, were used as process data to interpret these new additions and to capture ideas that students acquired during online reading phase but did not appear in their argument graphs. The protocols included information about the web pages that students visited, students' discussions during online reading, and actions that students took on the Web (e.g., browsing search results, reading web pages). The argument graph also provided process information about the order in which students generated argument boxes in their graph. With the help of this information, the point at which students generated each of the argument boxes was added to the transcribed protocols. This enabled us to relate the generation of each argument box to the web page that students were reading at that time as well as to the discussion segments that took place.

During the writing phase, students' joint essays were used as product data. The essays comprised, on average, 273 words (SD = 76). The Finnish language has a highly productive compounding system, a rich derivational system, and an agglutinative morphology (Aro, 2004). In Finnish, this results in producing more ideas with fewer words compared to English. Verbal protocols from the writing phase were used as process data to detect the additional ideas that came into play during the writing phase and were included in the essays. The writing phase used all of the data from previous phases (e.g., the prior knowledge phase and the online reading phase) in order to enrich the interpretation of students' essays.

3.5. Analysis of initial aspects of synthesis

The initial aspects of synthesis were analyzed by studying the prior knowledge activation and online reading phases together. We combined data from these two phases in order to evaluate the synthesis of ideas that involved online information and ideas that did not involve online information.

The sources of information in argument boxes were categorized by source as: 1) prior knowledge (PK) activated before reading, 2) online information, or 3) prior knowledge (PK) activated during reading. An argument box was classified as having originated in students' prior knowledge activated before reading when the students added it into the graph during the prior knowledge activation phase. When students added an argument box during the online reading phase and the content of the argument box was based on reading a web source it was classified as having originated from online information.

An argument box was classified as prior knowledge activated during reading when students added a box in the argument graph during the online reading phase but the information in the box was not clearly connected to a proposition on the web page, even though occasionally one or two words may have been similar in the two contexts. Typically, these originated from a discussion that was stimulated by a word or two that appeared on the web page, sometimes followed by a chain of associations. This often prompted the two students to discuss and exchange elements of prior knowledge, not previously activated during the prior knowledge activation phase, in relation to the online text elements.

The links between pairs of argument boxes were also analyzed and placed into one of the following seven categories: 1) PK activated before reading - PK activated before reading, 2) PK activated before reading - online information, 3) PK activated before reading - PK activated during reading, 4) online information- PK activated during reading, 5) PK activated during reading - PK activated during reading, 6) intratextual (link between two boxes that originated from same web page), and 7) intertextual (link between two boxes that originated from two different web pages).

3.6. Analysis of later aspects of synthesis

For understanding the latter aspects of synthesis, the essays were analyzed for the origin of the information and the quality of each essay. The analysis of the origin of the information in the essays proceeded in two stages. In the first stage of the analysis, essays were divided into idea units. An idea unit corresponds typically to a single verbal clause that expresses an action, event or state (Mayer, 1985). Idea units have been previously used successfully as a unit of analysis when examining reading and writing from multiple texts (Kiili, Laurinen & Marttunen, 2009; Gil, Bråten, Vidal-Abarca, & Strømsø, 2010; Le Bigot & Rouet, 2007). In the present study, students' essays included, on average, 42.21 (SD = 13.62) idea units.

In the second stage of the analysis, the origin of each idea unit was carefully tracked by comparing the idea units in each essay to the content of students' argument graphs, web pages that students read, and transcribed verbal protocol data in each of the different phases of the task. A sequence of analyses and decisions were made in relation to each idea unit appearing in the essay. Fig. 1 presents a taxonomic system of this tracking process and the categories used to determine the origin(s) of each idea unit that was tracked. There were three basic steps in the tracking process (see Fig. 1).

First, each idea unit in the essay was compared to the content in the argument graph to see if a similar idea appeared in the graph. If it appeared, the next step was to determine if it was entered into the argument graph during the prior knowledge phase or the online reading phase. Then it was evaluated in terms of whether the idea unit was equivalent to the content found in the graph or whether it was elaborated or transformed. In the latter case, the source or sources of elaboration or transformation were tracked from the verbal protocols during the three phases and the web pages that students read as long as a match was found. If a match was not found, it was considered that the elaboration had happened during the writing phase. Further, the previous analysis of the graphs was utilized when deciding whether the ideas originating from the graphs during online reading were based on online information or from prior knowledge activated during online reading.

Second, if the argument graphs were not able to serve as a starting point for the tracking process, the verbal protocols were explored. Each of the remaining idea units was compared to the verbal protocols in the order of their appearance. When the first match was found, it was compared as to whether or not the idea unit was equivalent with the content found from the protocols. If it was not, the tracking process continued in order to find the additional source(s) of the idea unit. In the case that the idea unit was found to appear in the verbal protocols of the online reading phase, we also explored web pages that students read at the time of their discussion. This was done to be able to decide whether the idea originated from the online source or whether the idea could be classified as prior knowledge activated during reading. Finally, each remaining idea unit was then compared to the content found at the web pages that students read. If it did not appear on any of the web

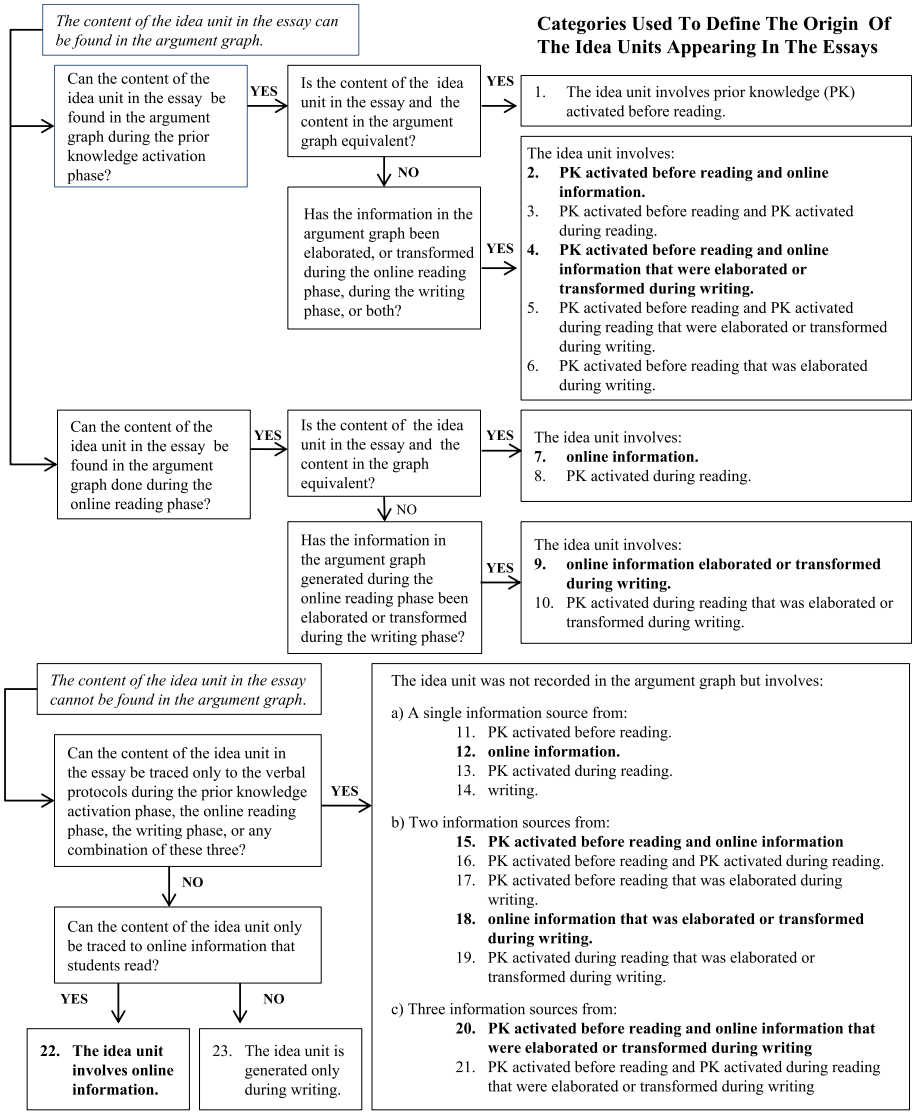

Fig. 1. The procedure to determine the origin of idea units appearing in students'essays. Notes: 1) PK = Prior knowledge. 2) Each category contains a reference number 1–23 that is also used in Tables 6 and 7. 3) Categories where students used online information appear in boldface (2, 4, 7, 9, 12, 18, 20 and 22).

pages, the idea unit was considered to be generated solely in the writing phase.

Two researchers analyzed the first two essays together in order to reach a clear understanding of the tracking procedure. Then, one person went through the tracking process with all idea units in each essay. Finally, an independent researcher coded three essays. These essays included 130 idea units, or 16.25% of all idea units. We found 83.9% agreement. In all cases, the initial coding was used in the analysis.

A scoring rubric was developed for evaluating the quality of the essays that reflected the task requirements and the general elements of a deliberation essay. In this type of the essay, students should consider different perspectives, examine both supporting arguments and counterarguments, and come to a conclusion after weighing the arguments (see also Mateos et al., 2018; Nussbaum & Schraw, 2007). In addition to these criteria, we also evaluated the coherence of the essay. Two researchers separately evaluated the quality of the essays in these four areas by using a three-point rubric ranging from 1 to 3 points. The scoring rubric used to evaluate the essays is presented in Table 1. The inter-rater reliability (Cohen's Kappa) for scores across all areas of essay quality was 0.79. All disagreements were discussed and resolved. Cronbach's alpha for these four items was 0.660.

The overall score, indicating the quality of the essays, was the sum of the scores for the four items with a maximum of 12. The mean overall score for students' essays was 7.58 (SD = 2.2) ranging from 4 to 12. Following scoring, the essays were organized into three levels: essays with scores below 6 were categorized as unremarkable essays (n = 4); those with scores from 6 to 9 as good essays (n = 11); and those with scores from 10 to 12 as excellent essays (n = 4).

Table 2 summarizes data sources, the units of analysis, and the target of the analysis.

3.7. Statistical analysis

The initial aspects and latter aspects of synthesis were analyzed according to the quality of essay performance. This helped identify relationships between various initial aspects of synthesis and successful essay performance. Kruskal-Wallis procedures were used for both, a conservative, non-parametric method for testing whether samples originated from the same distribution (Spurrier, 2003). Two-by-two comparisons were performed with the Mann-Whitney test, a conservative, non-parametric method for comparing frequencies within samples.

Table 1
Scoring rubric used to determine essay quality.

Area of essay quality	Quality score		
	1	2	3
Perspectives	An essay includes several perspectives some of which are irrelevant.	All presented perspectives are relevant including one of the two most important perspectives appearing on Finnish Web pages that discussed the topic: preventing the spread of child pornography and violating freedom of speech.	All presented perspectives are relevant including the two most important perspectives appearing on Finnish Web pages that discussed the topic: preventing the spread of child pornography and violating freedom of speech.
Argumentation	Writers' argumentation is biased either for or against the issue or the argumentation is exiguous.	Writers present arguments both for and against the issue but not in an integrated way.	Writers present arguments both for and against the issue in an integrated way.
Conclusion	Writers do not provide a concluding statement at the end of the essay.	Writers provide a concluding statement at the end of the essay without connecting it to previously presented ideas.	Writers provide a concluding statement at the end of the essay and explicitly connect it with previously presented ideas.
Coherence	The essay is organized as a separate list of ideas.	The essay is clearly organized but it lacks cohesive ties that link the paragraphs together or the cohesive ties are used in a mechanical way.	The essay is clearly organized and it forms a coherent whole. Cohesive ties are used in versatile ways.

4. Results

4.1. Initial aspects of synthesis

4.1.1. The sources of information in students' argument graphs

Table 3 shows that student pairs created an average of 20.42 total argument boxes ($SD = 6.42$). Approximately one third of argument boxes (35.83%) involved online information. These results suggest that affordances embedded in the graphic representational tool were easy to use, and thus, students utilized the tool regularly to support their work during the initial aspects of synthesis.

Table 3 also shows the sources of information in students' graphs by students' essay quality (i.e. excellent essay, good essay, and unremarkable essay) the determination of which is described in section 3.6. Student pairs developed roughly similar total argument boxes regardless of the quality of their essay ($X^2 = 0.66$; $p = 0.72$), and thus, the number of argument boxes used by student pairs did not discriminate between higher and lower quality essays. However, there was a significant difference between essay quality groups in the number of argument boxes involving online information ($X^2 = 6.93$; $p = 0.03$). Student pairs with excellent and good essays had nearly three times as many ideas from online information during the initial aspects of synthesis (approximately 46% and 42% of all argument boxes, respectively), compared to students with unremarkable essays (approximately 15%). Student pairs with an unremarkable essay appeared to rely substantially on their prior knowledge activated during reading ($M = 9.25$; $SD = 4.79$). This was more than four times as frequent as the pairs with an excellent ($M = 1.75$; $SD = 1.71$) or a good essay ($M = 2.27$; $SD = 1.85$). The difference between the essay quality groups in using prior knowledge activated during reading was also statistically significant ($X^2 = 7.51$; $p = 0.02$).

4.1.2. Links in students' argument graphs

On average, students made a total of 11.22 ($SD = 7.44$) links between argument boxes (see Table 4). The frequency of links ranged from 1 to 29 for each student. It appears that not all student pairs were able to take equal advantage of the argument graph tool to deepen their knowledge by thinking often about relationships between ideas in their argument boxes.

The most common type of link was made between two argument boxes, both containing prior knowledge activated before reading (33.33%), suggesting that initial synthesis often consisted of connecting previously known information with other, previously known information. Nearly half of the links between argument boxes (44.13%) were connected in some way to online information implying that students also drew upon substantial amounts of online information during the linking of ideas. However, intratextual (7.04%) or intertextual (8.45%) links were quite rare indicating the possibility that it may be easier for student pairs to connect prior knowledge to online information than to connect information either within or across online sources.

Table 4 also shows that there was no difference between the essay quality groups in the total number of links between argument boxes in the graphs. Thus, the number of links used by student pairs also did not discriminate between higher and lower quality essays. The groups differed, however, in the number of links that connected two ideas from prior knowledge activated during reading ($X^2 = 6.72$; $p = 0.035$). The pairs with an unremarkable essay made this type of link, on average, 3.75 times ($SD = 5.50$), whereas the corresponding number for the pairs with an excellent essay was, 1.00 ($SD = 1.41$) and the pairs with a good essay made this type of link, on average, 0.36 times ($SD = 0.92$). Pairwise comparisons showed that a statistically significant difference was found only between the pairs with good and unremarkable essays ($U = 4.5$; $p = 0.09$) but not between the pairs with excellent and unremarkable essays ($U = 4.5$; $p = 0.278$).

Table 2
Process Data and Product Data Sources during Each Phase of the Task, and Unit and Target of the Analysis

Phase	Process Data	Product Data		
	Data Source(s)	Data Source(s)	Unit of Analysis	Target of the Analysis
Prior Knowledge Activation	Verbal protocols	Argument box entries Links between argument boxes	Argument box Links	Sources of information Types of links
Online Reading	Verbal protocols o Web pages visited o Discussions during online reading o Actions on the screen taken during online reading o Order of argument box entries	New additions to the argument boxes	Argument box	Sources of information
Writing	Verbal protocols All process data from previous phases.	Joint essays	Idea units in the essays	Essay quality Origin of information

Table 3
Sources of information in students' argument graphs by essay quality.

Source of information	Excellent Essay (n = 4)			Good Essay (n = 11)			Unremarkable Essay (n = 4)			Total		
Argument Boxes	*M*	*SD*	%	*M*	*SD*	%	*M*	*SD*	%	*M*	*SD*	%
Not Involving Online Information												
PK activated before reading	9.00	1.16	45.57	9.09	3.48	46.74	11.00	4.55	46.32	9.47	3.32	46.39
PK activated during reading *	1.75	1.71	8.86	2.27	1.85	11.67	9.25*	4.79	38.95	3.63	3.89	17.78
Total	10.75	1.89	54.43	11.36	4.70	58.41	20.25	9.22	85.26	13.10	6.44	64.17
Involving Online information *	9.00	3.56	45.57	8.09	3.27	41.59	3.50	1.29	14.74	7.32	3.54	35.83
Total	19.75	2.75	100.0	19.45	6.06	100.0	23.75	9.95	100.0	20.42	6.42	100.0

Note. PK = Prior knowledge; *p ≤ 0.05.

4.2. Later aspects of synthesis

4.2.1. The sources of information in students' essays

On average, student pairs included 42.11 idea units in their essays (SD = 9.97). Slightly more than half of all idea units that appeared in the essays (406 out of 800) involved content that also appeared in the argument graphs, suggesting that the argument graphs may have also served a useful purpose during the later aspects of synthesis with helping to organize and synthesize information. One-third of all idea units in the essays (33.38%) involved online information and slightly more than one-third did not involve online information (39.75%). The remaining idea units were generated solely during the writing phase (26.88%). In their essays, students utilized information, on average, from 4.32 different web pages (SD = 2.00). One pair used one web page in their essay whereas on the other end of the continuum, one pair included information from eight different web pages in their essays.

Analyses were conducted to compare essay quality groups in relation to the origin of the ideas included in the essay (see Table 5). Overall, there was no difference between essay quality groups in the total number of idea units in students' essays (X^2 = 2.89; *ns*). However, consistent with the pattern found with argument boxes during the initial aspects of synthesis, there was a significant difference between essay quality groups in the actual use of *online information* within their essays (X^2 = 8.17; p = 0.017). Idea units involving online information appeared, on average, more frequently in the excellent (M = 19.75) and good essays (M = 15.01) compared to the unremarkable essays (M = 5.75). Pairwise comparisons showed differences between the students with excellent and unremarkable essays (U = 0; p = 0.021) as well as between the students with good and unremarkable essays (U = 3.0, p = 0.013).

Table 5 also shows that student pairs with the lowest quality essays used more idea units that did not involve online information than did the student pairs with the higher quality essays (X^2 = 7.97; p = 0.02). On average, unremarkable essays contained 30.25 (SD = 12.18) idea units that did not involve online information, while good essays contained 12.91 (SD = 6.12) idea units, and excellent essays contained 13.75 (SD = 3.78) idea units. Pairwise comparisons confirmed that the differences appeared between the excellent and unremarkable essays (U = 0; p = 0.021) and between the good and unremarkable essays (U = 2.0; p = 0.09).

The lack of online information use by the students who wrote unremarkable essays appeared to result from idea units that came from prior knowledge emerging from discussions during online reading. When looking at the two most common categories that included prior knowledge activated during reading, it can be seen that the essay quality groups differed in the use of prior knowledge as such (X^2 = 6.104; p = 0.047) and prior knowledge that was further elaborated or transformed during the writing phase (X^2 = 8.99; p = 0.011). For example, the percentage of these latter types of idea units for the unremarkable essays (11.9%) was about four times greater than those for the good essays (2.7%) and excellent essays (2.8%).

5. Discussion

Research has begun to elaborate our understanding of many elements of online reading including locating online information (Kuiper & Volman, 2008), evaluating online information (Wiley et al., 2009), and reading and writing to communicate online information (Leu et al., 2015). Relatively little work has taken place in synthesizing, or integrating, online information, despite its importance, perhaps because it is such a challenging area to study. This study advances that work with a methodology that permits the collection of multiple aspects of processing information in a complex, multi-faceted learning task, with minimal intrusion and interruption to processing. Thus, it provides direction for studying integrative processing in a setting more similar to the complex contexts that define classrooms today. The results point to the complexity of the processes, the distinction and similarities between early and later aspects of synthesis, and the challenges that some

Table 4
Links between the argument boxes by essay quality.

Type of link	Excellent Essay (n = 4)			Good Essay (n = 11)			Unremarkable Essay (n = 4)			Total		
	M	*SD*	%	*M*	*SD*	%	*M*	*SD*	%	*M*	*SD*	%
Links between ideas that involve online information												
PK activated before reading – Online information	1.75	2.36	18.92	2.82	3.49	24.80	1.00	1.41	7.84	2.21	2.94	19.72
Intertextual	1.00	1.16	10.81	1.27	1.49	11.20	0	0	0	0.95	1.31	8.45
Intratextual	1.00	2.00	10.81	1.00	1.67	8.80	0	0	0	0.79	1.55	7.04
Online information – PK activated during reading	0.50	0.58	5.41	0.91	0.70	8.00	1.75	1.5	13.73	1.00	0.94	8.92
Total	4.25	1.71	45.95	6.00	4.56	52.80	2.75	1.5	21.57	4.95	3.78	44.13
Links between ideas that do not involve online information												
PK activated before reading – PK activated before reading	3.00	3.83	32.43	3.73	3.72	32.80	4.50	4.36	35.29	3.74	3.68	33.33
PK activated before reading – PK activated during reading	1.00	0.82	10.81	1.27	2.24	11.20	1.75	1.71	13.73	1.32	1.86	11.74
PK activated during reading – PK activated during reading*	1.00	1.41	10.81	0.36	0.92	3.20	3.75	5.50	29.41	1.21	2.78	10.8
Total	5.00	5.35	54.05	5.36	5.48	47.20	10.00	10.13	78.43	6.27	6.52	55.87
Total	9.25	5.91	100	11.36	7.58	100	12.75	11.15	100	11.22	7.74	100

Note. PK = Prior knowledge; *p ≤ 0.05.

Table 5
Origin of the idea units by essay quality.

Origin Of The Idea Unit In The Essays	Excellent Essay (n = 4)			Good Essay (n = 11)			Unremarkable Essay (n = 4)			X^2	p
	M	*SD*	%	*M*	*SD*	%	*M*	*SD*	%		
Idea units involving online information											
Online information (7 + 12+22)	12.00	6.22	27.12	10.00	4.31	26.69	3.50	2.08	6.64	*8.177	0.017
Online information elaborated or transformed during writing (9 + 18)	5.25	4.11	11.86	3.73	3.04	9.95	1.75	1.71	3.32	2.576	ns.
Online information and PK activated before reading that was elaborated or transformed during writing (4 + 20)	1.50	1.29	3.39	0.55	0.69	1.47	0	0	0	5.289	ns.
Online information and PK activated before reading (2 + 15)	1.00	0.82	2.26	0.73	0.65	1.95	0.50	0.58	0.95	1.033	ns.
Total	19.75	8.26	44.63	15.01	5.85	40.06	5.75	4.11	10.91	*8.174	0.017
Idea units not involving online information											
PK activated before reading (1 + 11)	9.00	2.58	20.34	6.09	3.53	16.25	11.00	5.48	20.85	3.249	ns.
PK activated before reading that was elaborated during writing (6 + 17)	2.50	1.73	5.65	3.82	1.83	10.19	5.25	2.06	9.95	3.366	ns.
PK activated during reading (8 + 13)	1.00	0.82	2.26	1.91	2.51	5.10	7.00	3.83	13.27	*6.104	0.047
PK activated during reading that was elaborated or transformed during writing (10 + 19)	1.25	0.96	2.82	1.00	1.00	2.67	6.25	4.72	11.85	*8.986	0.011
PK activated before reading and PK activated during reading (3 + 16)	0	0	0	0.00	0.00	0	0.50	0.58	0.95	*7.941	0.019
PK activated before reading and PK activated during reading that were elaborated or transformed during writing (5 + 21)	0	0	0	0.09	0.30	0.24	0.25	0.50	0.47	1.311	ns.
Total	13.75	3.78	31.07	12.91	6.12	34.45	30.25	12.18	57.34	*7.970	0.019
Idea units generated only during the writing phase (14 + 23)	10.75	0.96	24.30	9.55	3.86	25.49	16.75	9.98	31.75	2.712	ns.
Overall total of idea units	44.25	8.96	100.0	37.47	9.03	100.0	52.75	22.81	100.0	2.885	ns.

Notes: PK = Prior knowledge; *$p \leq 0.05$.
Numbers in parentheses represent idea unit categories appearing in Fig. 1.

students face.

The current study begins the important methodological work that will be required in the future with larger sample sizes and greater control over a variety of individual differences (cf. Afflerbach, 2015), developing a more detailed understanding of how informational synthesis takes place within the contexts that define reading today. As reading moves online (OECD, 2010) and as social and collaborative problem solving and inquiry activities become increasingly important (Coiro, Sparks, & Kulikowich, 2018; von Davier & Halpin, 2013), it is essential to understand how synthesis and the construction of meaning and knowledge take place within these more complex contexts. Two aspects of this study may inform future research.

The taxonomy outlined in Fig. 1 informs research in this area since it permits an initial set of categories for the analysis of multiple source integration during collaborative, online reading. Eleven separate categories of idea units (see Table 5) derived in 23 ways (see Fig. 1) appeared in the analysis, indicating the complexities inherent in any analysis of synthesis; many different information sources were combined in many different ways. The structure of these information sources is likely to provide important entry into future analyses seeking to better understand how online readers integrate multiple online sources and develop new understanding about important ideas.

A second aspect of this study may also be helpful. In the more complex classroom contexts of today that include paired, collaborative work, the use of online information, and graphic representational tools, the methods developed in this study may provide important direction for studying processing in a more natural, less obtrusive, manner. Taking an interaction approach (cf. Miyake, 1986) with the use of an argument graph permitted us to observe some of the cognitive processing during synthesis, typically hidden or only accessible by more intrusive means such as think alouds. More intrusive means, such as think alouds, may distort cognitive processing in important ways and removes students from more natural contexts. In this study, thinking was obtained as a natural part of discussion and negotiation since graphic representational tools and collaborative work are a natural part of classroom lessons. Such an approach will be important to more carefully explore the effects of individual differences on synthesis during collaborative online research.

This was an initial study, however. As a result, it used a smaller sample size to begin to explore these more complex contexts by establishing data collection procedures, defining taxonomic constructs, and observing initial relationships. A small sample permitted a close examination into several aspects of this process that may provide important direction for more controlled studies. This close focus also resulted in several limitations that need to be carefully considered before discussing the results. Results must be interpreted in relation to the limited sample size and the task context that was designed to be supportive in many ways. Having identified these important general limitations, several results appeared in this study and are discussed below.

5.1. Early aspects of synthesis

Integrating ideas from multiple online texts seemed to be quite difficult for many adolescent readers, especially during the initial aspects of synthesis. While student pairs each generated over 20 argument boxes on average, only about one-third of these contained online information obtained during online reading. Moreover, while student pairs generated over 11 links between argument boxes on average, only about 15% of links connected two separate argument boxes with online information. Perhaps most telling was the observation that intertextual links only appeared about 8.5% of the time during the initial aspects of synthesis.

There may be several possible explanations for the limited use of intertextual information. It could be developmental, a function of the developmental level of these students. Goldman, Braasch, Wiley, Graesser, and Brodowinska (2012), however, found that a low frequency of intertextual links was also made by college students, implying that a developmental explanation may be less likely. The limited use of intertextual information could also be a function of limited processing capacity or a combination of both a developmental limitation and a limited processing capacity. It might also be a function of limited instruction since some work suggests that reading instruction has not frequently included a focus on intertextual connections (Hynd, 1999). Clearly, additional work is needed in this area to evaluate the limited nature of intertextual connections made by students. Instructional studies are especially called for to determine if instruction in this

area may support richer, more complex thinking, with more connections between multiple texts.

A majority of all links (85%) between argument boxes in students' graphs involved prior knowledge. Given their familiarity, ideas based on prior knowledge were probably easier to make connections with than new ideas that students found from online texts. This is consistent with earlier work in offline reading contexts (e.g., Bransford, Brown, & Cocking, 2000) and notions of connecting the known to the new (Anderson & Pearson, 1984). The somewhat infrequent integration of online information and the frequent use of prior knowledge may be a natural function of organizing prior knowledge to manage new and complex information at the beginning stages of understanding. It may also suggest an important, and useful, target for instructional support in classrooms that increasing integrate online information into learning. Future research in this area could define optimal instructional strategies.

The finding that upper secondary level students experience difficulty with connecting online information from multiple texts is consistent with previous research, indicating that readers often rely more on gathering facts instead of contrasting and comparing information from multiple texts (e.g., Bennett, Maton, & Kervin, 2008; Mateos & Solé, 2009). Many students appear to rapidly flutter from one piece of information to another - a way of working that leads to a fragile network of knowledge (Kirschner & van Merriënboer, 2013). This study, though, only involved upper secondary students. More research is needed with students throughout the grade levels. Until we begin to develop data from all developmental levels, we will not know the full extent of the challenge.

This study showed that students with excellent and good essays included nearly three times as many argument boxes involving online information in their graphs compared to students with unremarkable essays whereas students with less remarkable essays relied more on prior knowledge. Students with high quality essays, though, did not use more links between argument boxes involving online information. Students with less remarkable essays did link more frequently between two argument boxes involving prior knowledge activated during online reading. It may be that it was easier for these students to link between ideas from prior knowledge during the initial stage of synthesis, especially when it is activated and supported in a discussion with a partner.

5.2. Later aspects of synthesis

This study suggests that synthesis during later aspects is quite complex as students combined prior knowledge, online information, and ideas generated during writing in multiple ways in their essays (see Fig. 1). About one fourth of the idea units in the essays appeared to have come from the act of writing itself. While it is possible that these ”new ideas” were simply prior knowledge that had not been previously expressed, this result is also consistent with a substantial line of previous research that shows writing to play an important role in learning, helping to develop new ideas that writers had not previously possessed (Bangert-Drowns, Hurley, & Wilkinson, 2004; Newell, 2006; Rivard, 1994).

What seemed most visible, though, was that students with higher quality essays integrated three to four times as many ideas in their essays from online information compared to students with unremarkable essays. It could be that students with unremarkable essays relied more on prior beliefs and knowledge about the topic as opposed to online information when constructing their responses. However, students who wrote lower quality essays did not use online information in the same way as students with higher quality essays. They appear to have used the online reading experience more frequently to prompt ideas from prior knowledge. Student pairs with unremarkable essays often picked up isolated ideas or words from online texts and then engaged in free association to elaborate these ideas together without paying much attention to the context of the online information. Although these students engaged in active discussions, they seemed to rely on overextended inferences that were often cued by the surface features of a text (cf. Chan, Burtis, Scardamalia, & Bereiter, 1992). This pattern is consistent with the pattern during the initial aspects of synthesis, where students with excellent essays included more argument boxes involving online information compared to students with unremarkable essays.

In our examination of the later aspects of synthesis in the essays, we used idea units as the unit of analysis. This solution comes with some limitations. As an idea unit is a somewhat small entity, it only reveals synthesis at the micro-level. Thus, students' attempts to synthesize information, for example, within paragraphs were not examined. Our examination was also limited to the synthesis of ideas, neglecting the important aspect of whether students included the sources of the online texts in their essays, and whether they used this information in an integrative manner (Perfetti, Rouet, & Britt, 1999). Future research could combine these different aspects to reach a richer understanding of the collaborative synthesis of online information.

5.3. Representational tools supporting synthesis

Given the complexity of the task, collaborative online reading contexts may benefit from the use of a web-based representational tool such as an argument graph. Though this was not a controlled study designed to evaluate the use of an argument graph, three results suggest that the use of an argument graph may support many students.

First, more than half of the idea units in the students' essays included information that appeared earlier in students' argument graphs. This suggests the argument graph played a supportive role. Second, more than 11 links appeared for each student pair, on average, between argument boxes during the initial aspects of synthesis, making these connections between ideas available for the essay task without having to recall them (cf. Suthers, 2001). However, it is important to note that substantial variability occurred with respect to argument graph use and thus, not all students were able to take full advantage of the argument graph's potential for supporting the synthesis of ideas during learning to the same extent. It may also indicate that additional instruction and practice opportunities are required to successfully take full advantage of the argument graph for learning. Third, the use of a representational tool, such as an argument graph, may be especially useful within a collaborative reading context where it helps students to record and organize the most important ideas from multiple and complex sources: prior knowledge, online information, discussions, and additional information emerging from discussions. With the help of the argument graph, students were able to make their joint, and negotiated, learning visible during the initial aspects of synthesis so that it was useable during the later aspects of synthesis, the construction of the essay (see also Noroozi et al., 2012). These patterns suggest that additional work with representation tools, during online reading, may yield promising results to inform instruction.

5.4. Instructional implications

An especially visible finding from this study was that pairs with lower quality essays focused on the use of prior knowledge rather than online information, while pairs with higher quality essays were better able to use online information and relied less often on prior knowledge. There may be several possible reasons for this but it may be that students with lower quality essays were unable to make adequate use of the affordances provided by using online information during an inquiry task. These results may suggest the need for instruction that helps lower performing essay writers to include more online information and all students to integrate ideas from online information with other sources of information, including prior knowledge. This would permit them to provide richer, more complex ideas about a topic from online information and connect these ideas more frequently to their own prior

knowledge and to discussions with their partner. In addition, this study suggests that pairing higher performing readers and lower performing readers might yield important learning benefits for the lower performing readers as strategies are shared that show how to better use online information to develop understanding.

Since students with unremarkable essays relied so frequently on prior knowledge activated during reading in both the initial aspects and the later aspects of synthesis, it may also suggest that classroom attention should be paid to the nature of the discussions by student pairs during collaborative online reading activities. This also points to the importance of research taking place on discussion patterns within classroom learning contexts (Malloy & Gambrel, 2004; Murphy, Wilkinson, Soter, Hennessey, & Alexander, 2009). Work in this area may provide useful direction to inform research into collaborative online reading, helping us to better understand which instructional practices may help students engage in more productive talk around online information.

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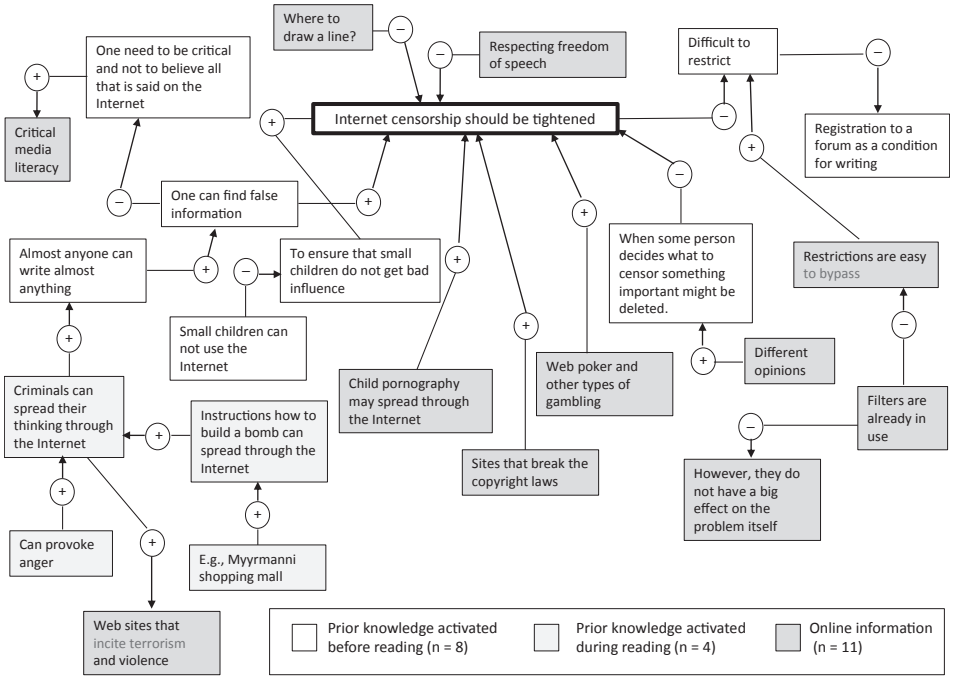
Appendix A

The Graph of a Student Pair that Wrote an Excellent Essay.



Appendix B

Task Assignment

Your task is to compose a deliberation essay where you consider different perspectives on the topic: *Should censorship be tightened?*

Phases of the task:

1) Construction of argument graph on the basis of your prior knowledge (15 min)
   - Your task is to discuss about the topic and collect reasons for and against the censorship into your argument graph
2) Searching of source material on the Internet to complete your argument graph (30 min)
   - Your task is to search for information of the topic on the Internet and supplement your graph on the basis of the information you have found.
3) Composing an essay (45 min)
   - Your task is to write a deliberative essay that considers different perspectives on the topic. Take advantage of the perspectives that you have collected to your graph.
   - You can title your essay the way you wish.

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