Knowledge Management & E-Learning, Vol.14, No.2. Jun 2022

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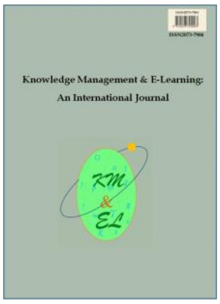

Knowledge Management & E-Learning: An International Journal (KM&EL)
ISSN 2073-7904

Recommended citation:
Campbell, L. O. (2022). Learner development through serial concept mapping. *Knowledge Management & E-Learning*, *14*(2), 170–185. https://doi.org/10.34105/j.kmel.2022.14.010

Knowledge Management & E-Learning, 14(2), 170–185

Learner development through serial concept mapping

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Abstract: In this study, individual serial concept mapping was employed as a learning approach to demonstrate learner development over time. Participants (n = 22) individually completed serial concept maps consisting of five iterations. A highly structured peer feedback process was employed to support interaction within learners' zone of proximal development. Learners' perceptions regarding the development of personal knowledge, process knowledge, and content knowledge were discussed, indicating positive growth in all types of knowledge. Concept mapping with a highly structured feedback loop promoted higher-order thinking skills such as analyzing, evaluation, reflection, and creative thinking. The highly structured peer reviewed process was noted by the learners as influencing learners' conceptual understanding and development of their serial concept map.

Keywords: Concept mapping; Novakian concept mapping; Iterative concept mapping; Serial concept mapping; ZPD

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1. Introduction

Concept mapping has been recognized as promoting meaningful learning (Novak, 1998). The visualization affordances of concept mapping provide learners and instructors an awareness of the learners' knowledge organization and representation of understanding. Concept mapping may be completed individually and collaboratively. Collaborative concept mapping includes two or more learners working in conjunction to develop a concept map and may be created as a one-time occurrence or as a serial concept map. A serial concept map is a concept map that changes over time. As learners' perceptions change due to new knowledge, their map will be revised to reflect new developments in thought.

The process of developing collaborative group concept mapping in a face-to-face environment advantages synchronous peer interaction and discussion and supports learners' cognition in their zone of proximal development (ZPD, Vygotsky, 1978; Novak, 1998). Conversely, online collaborative web-based concept maps are typically constructed asynchronously with minimal dialogue and interaction between the co-creators of the map, negating the support and guidance of a more knowledgeable other. While there are benefits of employing collaborative concept mapping, like brainstorming and developing a position, disadvantages include the plurality of knowledge representation. A collaborative concept map demonstrates group knowledge not an individual's knowledge or understanding. In online environments, map development may be dominated by one learner thereby neutralizing the benefits of meaningful learning, higher-order thinking development, process and content knowledge growth, and metacognition (Behfar, Peterson, Mannix, & Trochim, 2008).

Prior studies have called for additional research related to concept mapping including the role of serial concept mapping (All & Huycke, 2007), the sustainability of learner effort in serial map development (Roessger, Daley, & Hafez, 2018), using concept mapping to support higher-order thinking in problem-solving contexts (Wu & Wang, 2012), and web-based collaborative concept mapping (Wang, Cheng, Chen, Mercer, & Kirschner, 2017). Further, Cañas, Reiska, and Möllits (2017) called for research that examined concept mapping in relationship to higher-order thinking skills. Finally, while others have proposed that learner development in the ZPD is only realized through collaborative concept mapping (Sadler, Stevens, & Willingham, 2015), this study considered individually constructed concept maps with structured peer feedback. Individually constructed serial concept maps advantages the benefits of individual knowledge representation, while the structured peer feedback affords social interactions that contribute to cognitive development and growth. The purpose of the study includes investigating learners' perceptions of the process of individual serial concept mapping with structured peer review for evidence of learner development and higher-order thinking.

2. Literature review

2.1. Novakian concept maps

Novakian concept maps are concept maps that follow the principles developed by Joseph D. Novak (Novak & Gowin, 1984), grounded in the theoretical work of Ausubel's meaningful learning and advanced organizers (Ausubel, 1960). Novakian concept maps are constructed in response to a focus question for the purpose of demonstrating cognitive understanding related to the focus question. Novakian concept maps are comprised of propositions, composed of a concept, linking words, and concepts, which can be read as a sentence (see Fig. 1). Multiple concepts can be connected to linking words, but concepts are not attached to other concepts without linking words. A Novakian concept map demonstrates answers to a guiding focus question. Map designs are typically hierarchical and are representative of the creators' understanding of the overarching question. A concept map documents and organizes interrelationship-structures and mental models related to the concepts. Concept mapping develops critical thinking in that information is distilled down to its most important parts (Cañas, Reiska, & Novak, 2016).

In this study, there are three types of knowledge (i.e., content, process, and personal) explored. Content knowledge is demonstrated directly in the maps through the propositions that are developed and the conceptual knowledge of the content. Process knowledge indicates that learners demonstrate skills in questioning, analysis, and synthesis, all markers of higher order thinking skills. Personal knowledge is often evident through personal reflection statements such as (a) I feel more confident, (b) I believe I can . . . and (c) I am more organized. Both process and personal knowledge are indicated through self-reflection instead of being directly evident on the concept map. Process and personal knowledge as ways of thinking can be applied to other academic contexts.

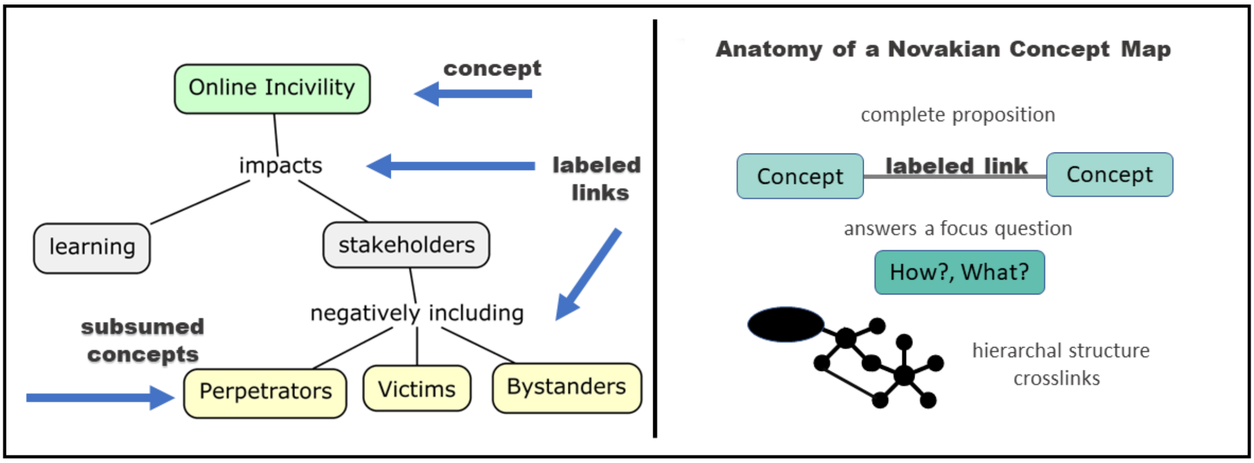

Fig. 1. Anatomy of a Novakian concept map

Concept mapping has long been associated with higher-order thinking. Prior research has noted that the process of building and revising a map requires higher-order thinking skills (Bramwell-Lalor & Rainford, 2014; Cañas & Reiska, 2018). There are many skills that contribute to the practice of higher-order thinking during map development including questioning, explaining, analyzing, reflective thinking, interpreting, synthesis and metacognition (Cañas et al., 2017; Wu & Wang, 2012). The process of moving concepts, links, and propositions to document interrelationships requires the learner to practice higher order thinking. In this study, we are operationalized higher-order thinking following the work of Cañas and colleagues (2017).

2.2. Serial concept mapping

Serial or iterative concept mapping has been practiced in education, nursing, science, and STEM (Campbell, 2009, 2016; Chiou, 2008; Daley, Morgan, & Beman, 2016; Nesbit & Adesope, 2006; Novak, 1998; Quinn, Mintzes, & Laws, 2003). Serial concept map development occurs over a period of time. Serial concept maps are characterized by the multiple iterations that lead to the completed concept map. For instance, a concept map could be started on a Monday and revisited several times during the week to demonstrate new information acquired or the timeline may be over the course of a month, quarter, semester, or year. Serial concept maps demonstrate differences in knowledge representation throughout multiple iterations (see Fig. 2). In this study, serial concept maps tracked cognitive structural changes over the course of a semester. Serial concept mapping as a process over time demonstrates learners' development over time (Cañas & Reiska, 2018). Serial concept mapping can be completed individually or collaboratively and should be assigned based on the desired outcome. Individual serial concept maps provide the individualistic perspective of the map creator making it easier to visualize students' ZPD when iterations are supported through human interaction. Conversely, group serial maps illustrate a group perspective and would not be indicative of an individual's learning development and internalization of knowledge. Serial concept mapping leverages time for reflection and revisions unlike one-time concept mapping.

Serial concept mapping provides more opportunity to develop higher-order thinking skills. Thereby, the learner engages in metacognition, a higher-order thinking skill. Higher-order thinking is evidenced in serial concept mapping as: (a) serial concept mapping reorganization relates to analyzing, (b) construction and refinement favors reflective thinking, (c) comparing the map to the focus question requires evaluation, and (d) crosslinks are indicative of creative thinking (Cañas, et al., 2017). Therefore, these indicators were adopted in this study as a framework to analyze higher order thinking.

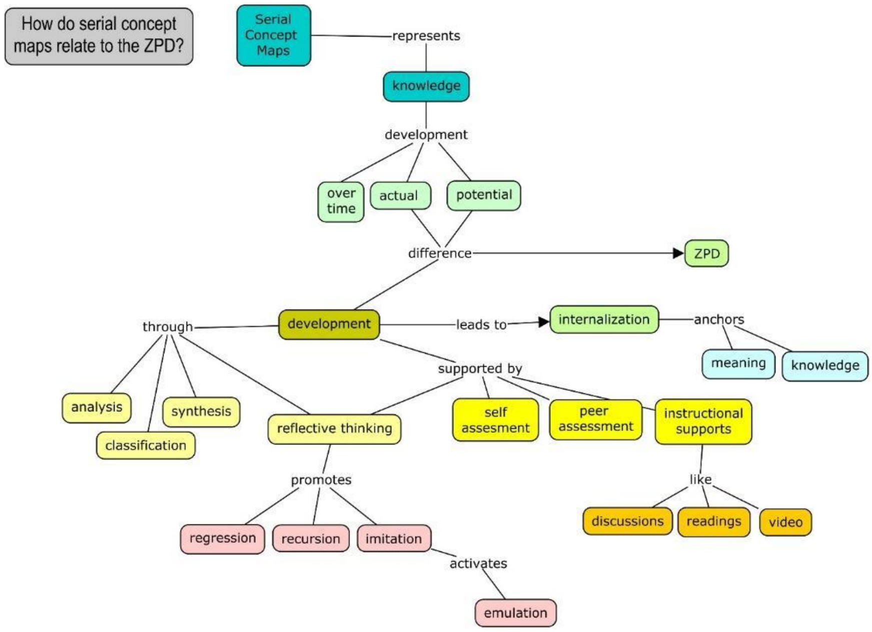

Fig. 2. Current knowledge representation of serial concept mapping and ZPD

2.3. *Vygotsky's zone of proximal development (ZPD)*

Novak and Cañas (2006) valued the contributions of Vygotsky's ZPD (1978) and Ausubel's (1963; 1968) theory of meaningful learning when discussing the benefits of concept mapping. Vygotsky described ZPD as the "distance between the actual developmental level (of the learner) as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). Vygotsky thought that the ZPD was a better way to assess intelligence than a test (Chaiklin, 2003). A learner-developed concept map provides visualization of a learner's development in answer to a problem or questions.

Therefore, this study seeks to investigate serial concept maps for evidence of Vygotsky's ZPD. Since conceptualizations and operationalizing Vygotsky's ZPD are ambiguous and difficult to ascertain as a working construct (Eun, 2019), this study proposes that serial concept mapping may be one way to visualize a learner's ZPD. If learning is developed to the point of being included on a concept map, understanding/development is evident. As the learner further develops and internalizes new knowledge, it becomes their new actual development level. Clark (2014) proposed that knowledge maps demonstrate multiple zones of proximal development. The ZPD is a conceptual framework explaining learning development through interaction. Hence this study considered individually constructed serial concepts maps with structured peer feedback to foster learner interaction. Foundationally, both serial concept mapping and the ZPD focus on the process of development rather than the outcomes of learning.

A proposed example of how individual serial online concept mapping with highly structured peer feedback relates to ZPD begins with the opening response to the concept map focus question (e.g., What effect does online academic incivility have on education?). Students' initial responses are memorialized on a concept map within their current level of development. After learners initially exhaust documenting their understanding, support and guidance for future development can come from self, peers, and instructors. These supports include:(a) readings, (b) discussions, (c) posed questions to guide further development, (d) self-assessment, (e) peer assessment, (f) exploration of other resources, and (g) reflection. Looking at other concept maps and word banks may prompt thought that leads to imitation and emulation of the examples (Vygotsky, 1978). It is within this interaction of support, that students are within their ZPD. Students are demonstrating their initial understanding and through interactions expand their knowledge each iteration documents the current level of understanding. Exploring serial concept mapping for ZPD and is novel. The potential of this study may provide a means for instructors to conceptualize learners' ZPD which could support future differentiated instruction.

2.4. Purpose of the study

Whereas concept maps can be developed within a group, this type of map development does not afford individual representation of knowledge (Novak & Cañas, 2006). Therefore, this study examined the process of individual serial concept mapping. The purpose of this study included: (a) investigating the development of individuals' serial concept mapping with structured peer feedback, and (b) identifying evidence of higher-order thinking through serial concept mapping. The research questions included:

RQ1: What are the learners' perceptions of serial concept mapping in relationship to personal, process, and content knowledge?

RQ2: To what degree do these serial concept map iterations evidence higher-order thinking?

3. Method

Data for the study was collected during the Spring semester 2018. The study took place at a large southeastern university. The class modality was online, with four online synchronous meetings. Students were required to complete the serial concept mapping assignment but chose whether or not their work would be considered for this study. Institutional review board status was exempt as this was a required assignment in a class. Participation in the research was completely voluntary.

3.1. Participants

The participants for this study were from a convenience sampling. Participants included (n = 21) female and (n = 5) male graduate students from an intact educational technology course. The majority of the participants were in master's degree programs (n = 23) while the remainder (n = 3) were students in a doctoral program for Teaching English to

Speakers of Other Languages (TESOL). Some participants were current teachers or in-training instructional designers. Of those who were current teachers, more than three-quarters of them had taught less than five years. Six identify themselves as being international learners. The total possible participants were N = 26. All students agreed to participate in the research, however, n = 22 completed the final survey and all completed all facets of the semester assignment. Attrition was accounted for due to personal reasons and were classified as course withdrawals (n = 2) and incompletes (n = 2).

3.2. Procedure

A serial concept map assignment was assigned to graduate students to be completed over a period of a semester (16 weeks). The timeline for the serial concept mapping assignment includes all elements of the assignment and the order the elements were completed which were: the concept map presentation (consisting of five iterations of the map, four self-evaluations, three to six peer evaluations), a post reflection survey, and the final self-reflection survey documenting the learner's perceptions of change (see Fig. 3).

Formation	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Completion
1. Develop Guiding Question 2. Download CMAP Tool	After Finish Module 1	After Module 2-3	After Module 4-5	After Module 6	1. Final Editing 2. Package Together 3. Write Reflection
	1. Create Iteration 1 2. Self-Evaluation 3. Revise 4. Peer Evaluation 5. Revise 6. Turn in Iteration 1 7. Review with Instructor	1. Add to Iteration 1 2. Self-Evaluation 3. Revise 4. Peer Evaluation 5. Revise 6. Turn in Iteration 2	1. Add to Iteration 2 2. Modify Existing Content 3. Self-Evaluation 4. Peer-Evaluation 4. Revise 5. Turn in Iteration 3 6. Review with Instructor	1. Add to and Modify Iteration 3 2. Self-Evaluation 3. Non-Classmate Evaluation 4. Revise 5. Turn in Iteration 4	
<<<<<<<<<<<<<< ← 16 Weeks → >>>>>>>>>>>>>					

Fig. 3. Timeline of serial concept map with expectations

3.3. Serial concept mapping as a process

At the beginning of the semester, during the first synchronous online class session, students were introduced to Novakian concept mapping. The interactive lesson included building a concept map as a class with the instructor to model the concept mapping development process. Steps included brainstorming, creating a list of related terms, and then building the concept map. Once a portion of the map was developed, the class was divided into smaller groups and sent to a virtual breakout room to build the next section of the map. Once that map was furthered developed, groups reconvened. In the main room, maps were deconstructed to help participants identify the elements of a concept map. Finally, the students received instructions and practiced developing a proposition using IHMC CMAP tools.

Next, students were scaffolded through developing an overarching question that their maps would answer through the semester. The students reviewed the course description, modules, syllabus, objectives, and assignments. Then, in small groups, students worked together to develop a version of the guiding question. Finally, once the class determined the question for the iterative concept map, the students reviewed the assignment guidelines and forms. This process was facilitated online similarly to the way it would have been in a face-to-face classroom (see Fig. 3).

The assignment required that after completing online modules in the class, learners revised their maps to reflect new knowledge and understandings from the online class, videos, readings, presentations, and other course assignments. Further, learners would facilitate their own peer and self-evaluations through a highly structured feedback loop and make further revisions to their maps. At the end of the semester, learners packaged together each iteration of their map, all peer- and self-reviews, and presented these elements in an online slide presentation. Learners then shared their work with the class for feedback. Finally, all learners completed a half-page summary about the process and completed a ten-question post-reflection survey regarding serial concept mapping (7 questions) and their basic knowledge of Novakian concept mapping (3 questions).

3.4. Structured peer feedback loop

The highly structured peer feedback loop included a template that asked the reviewer to analyze the map structure for certain elements (e.g., labeled links, crosslinks, and complete propositions). Next, the reviewers were asked to address the content: (a) Was the information accurate? (b) Were there areas of the concept map that were unclear? and (c) Were the propositions directly related to answering the focus question? The focus question developed by the learners stated: In what ways, do trends in instructional design, technologies, instructional strategies, assessment, and learning theories impact the design of teaching and learning for optimal learning performance inclusive of all learners in varying learning contexts? Reviewers then answered questions related to what they learned from reading and assessing the map that would guide their own map construction. The last part of the analysis included an open-ended question asking for additional feedback.

For iterations one, two, and four, peer review was completed by a classmate (a different person each time). For iteration three, the map was reviewed by someone not in the class or university. In most cases, learners chose a colleague from work or a friend whom they considered knowledgeable. This peer review did not include map structure questions. Rather, these reviewers answered these questions: (a) What do you think the concept map was trying to illustrate or communicate; and (b) Please indicate your thoughts about potential revisions or related ideas. Finally, there was an open-ended comment section. The map constructor was then required to respond to the peer analysis in their next self-assessment. They were not required to change anything but rather to explain their reflection on the comments.

3.5. Measures and materials

Concept map presentation. The semester-long serial concept maps and peer-review documents were analyzed for differences, comments, and evidence of struggle, triumph, and change (ZPD).

Post Reflection Survey. The post reflection conducted through Qualtrics included ten open-ended prompts that required short answers. The reflection form was developed and revised over the course of 5 years. Students' knowledge of concept mapping was determined by the four open-ended prompts like identifying the significance of links or what is a proposition. There were three open-ended questions/prompt related to the use of concept mapping in teaching and learning: (a) How can you utilize concept mapping in teaching?; (b) How can you utilize concept mapping in learning?; and finally the open-ended prompt (c) Concept mapping can … The open-ended prompt afforded opportunity for unguided exploration of concept mapping in teaching and learning. The final three questions required the analysis of the process and the product example topics included: (a) self-analysis of the learners' map developed over time, (b) the process of concept mapping, and (c) the purpose of a Novakian concept map and concept mapping in general. Learning development was measured through an analysis of the self-reflection comments recorded between CM iterations, the final reflection, and three questions on the post survey.

Final Self-reflection on Change. Students wrote a short self-reflection narrative that was presented in their concept map presentation related to the concept mapping development process and experience of how the maps change throughout the semester.

IHMC CMap Tools. This free digital tool, available through the *Institute for Human and Machine Cognition* at the University of West Florida, was used by students in this study to create their serial concept maps in the tradition of Novakian concept mapping (Novak, 1998). The program is fee-free to download. The program is available for PC, Macs, and iPads.

3.6. Data analysis

There were three ways the data was analyzed for this study. First, all open ended responses were semantically analyzed utilizing LIWC to determine the quality of the responses. Documents were digitally coded for key words through *Linguistic Inquiry and Word Count* [LIWC] (Pennebaker, et al., 2015) and then hand-coded for evidence of support related to map development. The LIWC program measures words in four different categories: Analytical Thinking, Clout, Authentic, and Emotional Tone. Words are counted in the selected text and compared to words in the built-in dictionaries for each of these categories. Category meanings are as follows: (a) clout refers to confidence, (b) authentic/authenticity refers to honesty or hedging in writing, and (c) emotional tone refers to the affect. Whereas the analytic thinking category is determined algorithmically based on the way words are used.

Next, to determine learners' map development the final presentation, post surveys, and reflections were analyzed. First, statements were extracted into a spreadsheet and then coded by two graduate students and one professor in several ways to answer the research questions. The analysis to answer RQ1 began by identifying the related words that were common across statements (see related words in Table 2). The frequency of these words was calculated. However, the frequency was not an indicator of significance but rather another way to classify the data for identifying patterns. A thematic analysis was conducted resulting in six themes. Next, statements were interpreted to be process, content, or process/content statements. Additionally, the statements were categorized into personal development (PD), content development (CD), and process development (PRD). Content development indicated that learners learned more about the content. Process development indicated that the learner perceived they had acquired more academic skills in synthesizing and analysis. Further, process development could include evidence of employing higher order thinking. Personal development encompassed affective statements from the learner like “I felt more comfortable”. To answer RQ2, the final presentations were viewed to identify differences between iterations. A holistic evaluation of the assignment from first to final iteration noted higher-order thinking when the maps were: (a) reorganized, (b) redefined, (c) comparing the map answered the focus question, and (d) evidenced crosslinks between iteration.

In this exploratory case study, the intervention of serial concept mapping with structured peer feedback was described. Validity of the study was established through the following means: (a) construct validity included multiple data sources, and (b) external validity was established through the related theoretical frameworks (Yin, 1994).

4. Findings

In this study, 22 concept maps, and their accompanying self-assessments, peer-assessments, and reflections were analyzed for learners’ perceptions of content, process, and personal development. Maps and self-assessments were examined for evidence of higher-order thinking skills. Finally, learner perceptions of the peer-feedback process, unique to this study, were considered. To assess the quality of the self-assessments, they were analyzed as one unit via *Linguistic Inquiry and Word Count* (LIWC), a digital tool for analyzing text (Pennebaker et al., 2015). Linguistic domains of analytic, clout, authenticity, and tone were calculated from the n = 18, 056 words in the sample (see Table 1). Each linguistic domain (analytic, clout, authenticity, and tone) is calculated on a 100-point scale. The analytical score was relatively high, indicating formal, hierarchical thinking. Regarding clout, out of 100 possible points, a lower number suggests a tentativeness about the writer's level of expertise. The authentic number was very high indicating an honest response. The emotional tone number was closer to 100 indicating a positive, upbeat style (Pennebaker et al., 2015).

Table 1
LIWC analytics

Word Count	Analytic	Clout	Authenticity	Emotional Tone
18,056	71.67	38.10	90.22	81.02

Next, the learners’ responses and reflections were coded for evidence of: (a) themes, (b) process or content comments, and (c) development. Finally, all iterations were viewed to determine if there was development between each iteration.

RQ1. What are the learners’ perceptions of serial concept mapping in relationship to personal, process, and content knowledge? To answer research question one, responses to the open-ended post survey questions (n = 66) about concept mapping were conducted. Eighty-two comments were collected from the three post survey questions. Frequency counts were conducted of key words and phrases. The top six themes are presented along with related words (see Table 2).

There was equal evidence that the learners in this study considered that they developed both in the process of developing a map and in the course content. A Pearson correlation was conducted to determine the relationship between evidence of process and evidence of content (n = 56) in the learners' comments r = -.428, p = .047 indicating a statistically significant moderate negative correlation.

Table 2
Post survey analysis

Theme	Frequency	Related Words	Process/Content
Concept mapping is beneficial to students.	11	Students, process, helps	Process
Concepts with links make sense of relationships.	10	Establish connections	Process
Concept mapping helped to visualize initial and deeper thinking and growth over time.	21	Deeper thinking, metacognition, thought processes	Content
Concept map iterations demonstrated knowledge and understanding, even though sometimes it was hard to do.	14	Understand ideas and the question, explain information	Content
Concept mapping developed abilities to synthesize through the process of reduction.	12	Synthesized, simplified, most important parts	Process / Content
Concept mapping made me learn more about concept mapping and more about the question.	20	Tool, process, readings, and discussions	Process / Content

Note. In some cases, comments included more than one theme

Approximately 55% of the learners indicated that they grew personally as a learner and in the way, they were able to synthesize and think (see Table 3). Regarding content development, 100% of the learners indicated content growth beyond instruction and assignments, as they needed to completely understand content to add it to their concept map. Growth and understanding of map process development was indicated by 95% of the learners. Most learners (n = 18) in this study indicated that their maps could continue to change as they developed as learners. The other four learners felt as if they had nothing to add nor would they in the future, as they considered their knowledge to be fully developed.

RQ2. To what degree do these serial concept map iterations evidence higher-order thinking? Next, the map structures were considered, from inception to the final iterations. Regarding the observed quantity of elements that comprised the concept maps, there was a general increase in the quantity of nodes, propositions, links, and interrelationships indicative of map development up to iteration three, which was expected as new instruction was introduced that related to the maps. In 16 of the maps, there was a reduction in propositions between iteration four and the final map. All maps changed from their initial structures to their end-of-course maps. In four cases, the initial maps were not hierarchically structured. However, all of the final maps were hierarchically structured with additional levels of hierarchy that were not evident in the first two iterations.

Table 3
Representative learners' perceptions of development: Process (PRD), content (CD), and personal (PD)

Learner Comment	Development Type
"I can see how I've evolved from my first iteration to my final iteration."	PRD
"Creating a Novakian Concept Map has truly allowed me to work on my developmental, analytical, and organizational skills. I often spend a lot of time "doing" rather than taking the time to properly analyze and think about what is the most effective way to "do"."	PRD
"This was the first assignment I have had where I revised the assignment throughout the entire semester and was able to look back on the assignment to visually and conceptually see how my thought process and understanding of a structure has changed."	CD
"I witnessed progress in my own thinking and understanding of the answers to the question. I unraveled several ideas related to the topic which is shown through the increase in the amount of detail from my first to my final iteration. It is a good learning experience to witness one's own progress and development in the understanding and application of a topic."	CD PRD
"I learned how to interrelate and organize many ideas derived from a broad topic. I also gained knowledge on new ideas that I had not thought of from reviewing my peer's concept maps."	PRD CD
"I was constantly analyzing my concept map each step of the way to see if I could communicate relationships better than I had before in the previous iteration."	CD PRD
"Once I started the first couple of iterations, I started to feel more comfortable with concept mapping as a strategy since I began searching for more resources to help reinforce my knowledge-base of Novakian concept mapping, and the topic area of the guiding question."	PD CD

To determine evidence of higher-order thinking, maps and self-assessments were coded for difference in iterations based on Cañas, Reiska, and Möllits's (2017) higher-order thinking scheme. The quantity of the elements was not of concern, but rather the evidence of behaviors was considered: a) serial concept mapping reorganization relates to analyzing, (b) construction and refinement favors reflective thinking, (c) comparing the map to the focus question requires evaluation, and (d) crosslinks are indicative of creative thinking. The following table indicates the number of learners who evidenced the higher-order thinking skills by iteration, except in the case of analyzing, which was tabulated based on new evidence of structural reorganization in each iteration (see Table 4).

Comments regarding the higher-order thinking were evidenced in both the iteration self-assessments and the final reflection. Learners indicated that they were engaged in higher-order thinking skills (see Table 5). Approximately 82% of the learners in this study evidenced higher-order thinking skills in the final iteration. The structured feedback loop reflection comments were additional evidence of higher-order thinking skills being employed during map modifications and subsequent concept map restructuring.

Table 4
Evidence of higher-order thinking in iteration and reflections

Higher-Order Thinking Skills	Iteration #2	Iteration #3	Iteration# 4	Iteration #5 Final
Analyzing (new) [reorganization]	22	3	2	3
Reflective thinking [construction and refinement]	22	21	20	9
Evaluation [comparing to focus question]	22	16	19	17
Creative thinking [crosslinks]	7	14	16	18

Table 5
Representative learner comments related to higher-order thinking

Higher-Order Thinking Skills	Learner Comments
Evaluating / Reflective Thinking	"The whole experience with this assignment allowed me time to reflect, reiterate, and reinvestigate the same guiding question several times throughout the semester."
Analyzing / Reflective Thinking	"The tediousness of going back and editing the map allowed me to see the huge transformation that came forth from taking the time to really analyze and develop the flow of the concept map."
Creative Thinking / Reflective Thinking	"During the self-assessment process, I noticed that I focused on the interrelationships and if they were identified properly or could use additional clarification. From self-assessing the map, I located areas that needed clarification (cross links and bidirectional arrows)."

5. Discussion

An individual serial concept mapping study with highly structured peer feedback was conducted over the course of a semester in a graduate education class. Learners created maps to answer a class-developed focus question related to the course content utilizing a digital concept mapping tool, IHMC CMap tools. Learners' initial maps were constructed at the beginning of the semester. Maps were revisited four additional times as learners completed new modules of instruction. This study is unique in that it attempts to quantify students' interactions as evidence that learners' creating a single author concept map with structured peer feedback can provide visualization of a learner's ZPD and the practice of higher-order thinking skills when the map is developed over time. Each iteration of the single-authored concept map provided evidence of development over time. Learners' actual development is dynamic and the differences between iterations document the previous potential development (Vygotsky, 1978) (see Fig. 4).

Learners' perceptions of process and content knowledge demonstrated that serial concept mapping with structured peer feedback equally supported both learner growth in process and content knowledge. The relationship between process and content knowledge was correlated that when process knowledge went higher, content knowledge went lower and vice versa. The relevance of this finding is unclear. Further consideration is warranted in future research. Like (Nesbit & Adesope, 2006; Campbell, 2009; Schroeder et al., 2018) all the learners in this study indicated that they gained content knowledge beyond the instruction they received in the class. Some of their increased content knowledge and subsequent understanding of the relationship to that knowledge is attributed to learners' motivation to develop their map more completely for a round of peer evaluation. Novak (1977) referenced his theoretical alignment with Vygotsky as it related to language mediating higher levels of cognition. In this study, the interaction caused the learners to consider each aspect of their maps prior to peer feedback. The structured feedback loop supported metacognition, a high-order thinking skill.

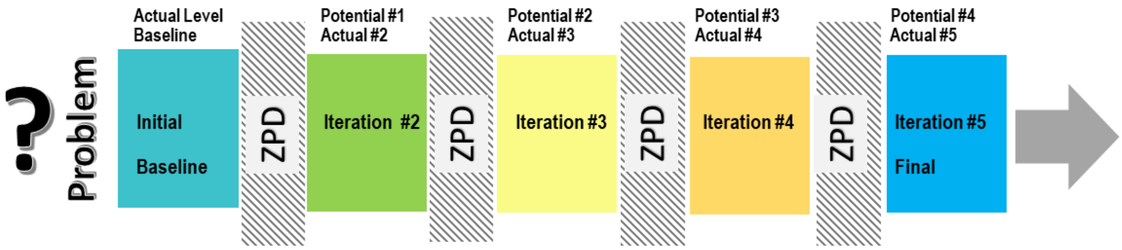

Fig. 4. Concept map of ZPD and serial concept mapping

Cañas, Reiska, and Möllits (2017) contextualized how higher-order thinking skills are activated during serial concept mapping development. The findings from this study indicated that every learner in the study demonstrated the activation of higher-order thinking skills beginning at iteration two, through iteration four. There was not a peer-review feedback cycle for the final iteration, which may have contributed to diminished demonstration of higher-order thinking skills. Further, the end-of-the-semester student fatigue and the reality of a completion grade may have contributed to the four participants not making changes between iteration four and the final iteration. Reflective thinking resulting in construction and refinement of concepts was the most recognized evidence of higher-order thinking. The development of higher-order thinking skills through serial concept mapping is promising. The transferability of these new-found skills to other contexts are unknown and could be considered in future studies.

The findings of this study demonstrated that serial concept mapping afforded visualization of learners' ZPD, extending Clark's (2014) idea regarding the development of a knowledge map. Increases in the quantity of nodes and propositions to answer the focus question from iteration one through three indicated growth. The regression and reorganization of concepts found predominantly between iteration four and the final iteration indicated an internalization of concepts. The learners' self-assessments supported that they had found ways to reclassify concepts to be more inclusive of other concepts.

Another encouraging finding of this study is the effectiveness of the highly structured feedback system promoted in this study. The learners valued the feedback from their peers as much as they felt being a reviewer benefited the development of their own maps. After each iteration, maps went through self and peer assessment to ensure the required structural elements were evident in the map. Learners spoke with each other and an outside peer reviewer. Some learners remarked that these interactions help them to solidify their position and development of the content (Novak & Gowin, 1984). The support of others (peer feedback loop) fostered additional development and a broader understanding of the interrelationship of concepts (Vygotsky, 1978). Future studies should incorporate a structured feedback loop to support student growth and to support learners in their ZPD.

Unlike Roessger, Daley, and Hafez (2018), the majority of the learners in this study indicated that they had not reached learning plateaus. Rather, learners indicated that their maps could continue to be expanded and redeveloped. Some learners indicated that the peer feedback helped them push past their own perceived mental block to a new level of development during the structured peer feedback loop. Moreover, this finding supports Vygotsky's more knowledgeable principle. Peer interaction through feedback supported learner development.

6. Conclusion

In this study, Novakian concept mapping provided a structured space for students to reflect on the course content in a reductionist manner. The study provided evidence that individual serial concept mapping with structured peer feedback fostered interactions that may support learner development in their ZPD. These results are similar to collaborative concept mapping (Brown & Ferrara, 1985; Kinchin, Hay, & Adams, 2000) but are unique in that these maps were constructed by individual learners. Learners indicated that they were engaged in metacognition and were supported by a more knowledgeable other (Vygotsky, 1978). Perceptions of growth were realized in the development of personal, process, and content knowledge.

The findings of the study have the following implications. Like collaborative concept mapping, individual serial concept mapping with structured peer feedback afforded learners a means to interact and discuss their development with others. Furthermore, the benefits of individual knowledge representation were realized. Educators seeking to develop higher-order thinking skills, as well as process and content knowledge, could consider incorporating individual serial concept mapping with structured peer feedback over the course of a quarter or semester. Additional research of the optimal time between constructing iterations would help educators plan the use of serial concept mapping as a learning tool. Besides memorializing learning and development related to the course content, serial concept maps can be a learning resource when preparing for future comprehensive exams. The entire course can be distilled down to its most important parts.

This study has several limitations. Learners' self-reported data was collected in association with a learning assignment. Learners may have unconsciously or consciously engaged in response bias. However, the fact that the learning assignment was associated with a completion grade may have negated response bias. Further, there was evidence of homogeneity in the responses, meaning there may not have been response bias at all. The qualitative nature of this exploratory study and the small sample sizes means that the findings should not be generalized to other settings. Finally, observations of higher-order thinking were determined based on a relatively new framework conceptualized by Cañas, Reiska, and Möllits (2017). Future studies should consider additional forms of higher-order thinking skills and the quality of student-constructed concept maps (Cañas, Novak, & Reiska, 2015) not considered in this study.

Author Statement

The author declares that there is no conflict of interest.

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