EXAMINING THE LEARNING-BY-TEACHING PROCESS THROUGH CONCEPT MAPS

by

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ABSTRACT

Learning-by-teaching has been shown to be an effective strategy, but research in the area lacks standardization. Studies have found that simply preparing to teach can be more effective than other learning techniques, although teachers' learning can be inhibited by failing to engage in metacognitive strategies. Concept mapping can facilitate deeper learning by organizing knowledge. The present study, therefore, incorporated concept mapping before participants taught material, allowing for an examination of the cognitive processing occurring while preparing to teach. The effects of both teaching and concept mapping on learning were examined, as well as the interaction between the two, both immediately after learning and after a delay. The results did not indicate that teaching and concept mapping provided greater benefits than only reading. Those who taught, however, completed more accurate concept maps than those who did not, providing further evidence for the cognitive organization occurring while preparing to teach.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I: INTRODUCTION

Overview

It has long been an assumption in many cultures, dating back to ancient proverbs, that learning-by-teaching is one of the most efficient learning strategies. For instance, Aristotle has famously quoted that "Teaching is the highest form of understanding." Similarly, the French essayist Joseph Joubert has said that "To teach is to learn twice over." Early research testing this idea found that tutors showed learning gains as great as, or even greater than, their tutees (e.g., Allen & Feldman, 1973; Cloward, 1967). One meta-analysis reported tutors outperforming non-tutors on tests and possessing more positive attitudes towards the learning material (Cohen, Kulik, & Kulik, 1982). The learning-by-teaching method was perhaps first implemented as a formal educational tool termed *Lernen durch Lehren* (LdL) ('Learning-by-teaching' in German) by Jean-Pol Martin in Germany in the 1980's (Grzega & Schöner, 2008). Learning-by-teaching research has seen a rise in popularity as of late, but many questions remain about the method. The following sections will review the literature on learning-by-teaching, including the processes and variables involved.

Learning-by-Teaching

In a review of the learning-by-teaching literature, Duran (2016) described the seven main categories of learning-by-teaching that are currently used in education. The first was learning by developing educational materials that will facilitate others' learning, such as videos. The second was learning by replacing the teacher in front of the class. This is a main facet of the LdL method used in Germany. Grzega and Schöner (2008) surveyed students who participated in LdL methods to examine the perceived efficacy of this method. Respondents indicated they felt they had developed the necessary competencies to function in knowledge societies and that they did not believe any other learning methods would have been more effective. The third method was learning-by-teaching through cooperative learning techniques (Duran, 2016), such as the Jigsaw technique (Slavin, 1995), in which students split into groups. Each group focuses on a specific part of the learning material and then take turns teaching their topic to the other groups. Fourth was cooperative learning techniques (Duran, 2016). Cooperative learning techniques focus more on group interaction, and students take turns being the learners and teachers. Fifth was peer tutoring which is a commonly used learning-by-teaching technique. In this method, the tutee and tutor's roles are typically fixed. Overall, research on peer tutoring shows evidence for positive learning effects of tutoring others (Topping, 1996). A sixth method used was peer assessment, in which students learn by correcting and providing feedback to other students. The final learning-by-teaching method Duran (2016) indicated was students acting as co-teachers, whereby they teach the material together to others.

The learning-by-teaching method is efficacious in many settings, even outside of traditional classroom settings. For example, Aslan (2015) found that science teachers reported Martin's learning-by-teaching method effective in gaining 21st century skills, such as communication, self-efficacy, and teamwork. The method has also gained popularity in medical and nursing schools. Gregory, Walker, McLaughlin, and Peets (2011) discovered greater learning gains among those who prepared to teach and subsequently taught younger students in their program unfamiliar medical tasks compared to those who only prepared to teach but did not teach. Applying the paradigm to a workplace setting, Cortese (2005) found in interviews with managers that learning-by-teaching was regarded as the most helpful learning tool, showing advantages over formal training, focus groups, reading, and learning from one's own experiences. Additionally, Lee, McNamara, Pitt-Catsouphes, and Lee (2014) found that opportunities to train others at work are associated with higher levels of job satisfaction and engagement.

Outside of the LdL method used in Germany and school tutoring programs, the learning-by-teaching method has not been widely implemented in formal educational curriculums elsewhere. While there is empirical evidence of the method's effectiveness, much of this research is fairly new and not comprehensive. Additionally, much of the conclusions on the efficacy of the method are based on peer tutoring research, which may not be representative of all learning-by-teaching situations. Much of this research may be confounded by the fact that tutors likely have greater knowledge in the content area to begin with. Less research has been conducted that examines learning-by-teaching with unfamiliar topics. Additionally, the research on learning-by-teaching utilizes a variety of the six methods described by Duran (2016), so it is not clear which of the methods are most effective for teacher learning.

Though research has found evidence that teaching is an effective learning activity, the mechanisms of the learning-by-teaching process, including which stage of the process is responsible for the positive learning effects, are not fully understood. For example, some research suggests that the learning effects of teaching can be attributed to preparing or expecting to teach and the resulting enhanced mental organization and summarization of the material (Bargh & Schul, 1980). Some research suggests that the effects are due to the process of explanation, even to fictitious others (Fiorella, 2014). On the other hand, other research contends that actually teaching to another person is more efficacious, perhaps because of the effects of interacting with and answering questions of the tutees (Webb, 1989).

Figure 1 provides a model of the learning-by-teaching process, including the mechanisms that are theorized to aid learning in each stage based on the ideas of Bargh and Schul (1980). The purpose of the present research is to clarify the learning benefits that result from the first two stages of the process by testing knowledge at these stages. The present study will also utilize concept maps, tools for organizing and categorizing knowledge, to assess knowledge and to examine the cognitive processing that is occurring when preparing to teach and explaining.

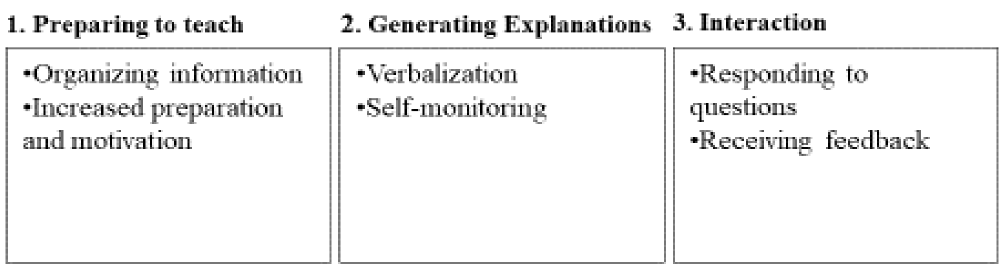

Figure 1. Theorized mechanisms in each phase of the learning-by-teaching process.

Phase one: Preparing to teach. Bargh and Schul (1980) provided one of the first studies to separate the stages of learning-by-teaching into preparation, explanation, and interaction. They suggested that interacting with tutees is a separate stage of learning in which teachers are forced to re-explain the material and identify their own knowledge gaps. Bargh and Schul (1980) concluded that that there does appear to be a cognitive effect involved with teaching, which is present in the preparation phase. They also found that actually teaching is not necessarily more efficacious than only preparing in enhancing the tutors' generalized knowledge.

Additional studies (Benware & Deci, 1984; Fiorella & Mayer, 2013; Fiorella & Mayer, 2014; Nestojko, Bui, Kornell, & Bjork, 2014) have found that expecting to teach leads to greater knowledge gains than expecting to take a test. This can be due to differences in preparation, better mental conceptualization, or increased motivation. Other research has been mixed; no significant positive effects of teaching expectancy versus testing expectancy were found by Ehly, Keith, and Bratton (1987), Renkl (1995), and Ross and DiVesta (1976). The present research seeks to provide clarity regarding the effects of preparing to teach versus teaching.

Phase two: Generating explanations. Other research has found that actually explaining or teaching may provide greater benefits than simply preparing to teach. In a classic study, Annis (1983) found that those who prepared to teach and actually did teach performed better than groups who a) were taught the material, b) only read the material, c) read the material and were taught, and d) prepared to teach but did not teach. This suggests that act of teaching may be more effective than the act of preparing to teach. However, those who taught in Annis' study interacted with other students, so one cannot determine whether the results occurred due to the act of explaining, interacting with the students, or some statistical interaction between explaining and interacting with students. Eliminating the socialization, tutee questions, and nonverbal cues involved with teaching will make the act one of self-explanation, which is an effective learning strategy (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, de Leeuw, Chiu, & LaVancher, 1994; King, 1992; Renkl, Stark, Gruber, & Mandl, 1998). Across 54 studies, Fiorella and Mayer (2015) determined that in 44 of those, self-explainers outperformed groups who did not self-explain on post-tests (d = 0.61).

Fiorella and Mayer (2013) attempted to better understand the phases of the process by examining whether actually teaching will be more efficacious than preparing to teach if the social aspect of teaching is eliminated. The authors did this by having tutors explain the material while isolated on video, as if it would be watched by a learner later. They hypothesized that preparing to teach would improve comprehension test scores on the immediate test but not the delayed test, and that those who actually did teach would show improved learning gains in both the immediate and delayed tests. These premises were based on prior research (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; King, 1992; Roediger III & Karpicke, 2006) which had demonstrated that generative learning, in which the learner obtains a deep understanding of material and integrates it with their prior knowledge, is most apparent after time delays. Fiorella and Mayer (2013) hypothesized that preparing to teach would result in more organized mental representations of the material better suited for an immediate test but that only those who actually teach would engage in the deep cognitive processes associated with generative learning. Their proposed hypotheses were supported in that both those who prepared to teach and those who taught performed better on the post-test than those who prepared to take a test, and that after a one-week delay, those who taught performed better on the post-test than those who prepared to teach and prepared to test. One limitation of this experiment is that those who provided the lectures spent an additional 5 minutes with the material than the other two groups did; this does not allow for strong conclusions to be made about the increased effectiveness of the teaching method.

In 2014, Fiorella and Mayer extended their earlier study by conducting two experiments examining the extent of generative processing in the first two stages of the learning-by-teaching process as suggested by Bargh and Schul (1980): preparing to teach and explaining to others without social interaction. In the first, participants studied a lesson on the Doppler effect with either the expectation to teach or take a test; participants read either a standard version of the text excerpt or an enhanced version which included learning tools such as segmentation, headings, and diagrams, to determine if those preparing to teach were better able to mentally organize the information. Those who prepared to teach, however, performed better than those who prepared to test, regardless of text format.

In Fiorella and Mayer's (2014) second experiment, participants again studied with the expectation to teach or take a test. All participants read the same version of the text excerpt on the Doppler effect. The authors attempted to examine the effects that preparing to teach has on teaching to determine if there was an interaction between the two. This experiment found that those who taught with the expectation of taking a test showed small positive effects relative to the control group, while those who expected to teach and taught had the highest performance of all groups. As consistent with their previous research, it was expected that there would be no main effect of teaching expectancy on the delayed test; this was confirmed. Surprisingly, those who expected to teach but then only tested performed worse than those who expected a test.

Fiorella and Mayer (2014) controlled for the amount of time each participant in the various conditions spent with the material. However, one limitation of experiment two is that in some sessions of teaching, one participant waited outside a hallway while another student recorded their lecture. The waiting participant would then record their lecture after the first participant finishes. Unfortunately, there is not a way to determine whether those waiting the extra five minutes were mentally rehearsing their own lecture or thinking about the material. The present research alleviates this limitation. Overall, findings from the Fiorella and Mayer (2014) study suggest that while preparing to teach may enhance short-term knowledge, both preparing to and actually teaching combined can aid longer-term knowledge.

Explaining to fictitious others. Termed the social facilitation effect, there is evidence that the simple presence of others can have positive motivational effects, such as increased attention (Bargh, 1994; Zajonc, 1965). The findings by Fiorella and Mayer (2014), however, as well as others who have experimented with pedagogical agents, or virtual tutees, (e.g., Biswas, Leelawong, Schwartz, Vye, & The Teachable Agents Group at Vanderbilt, 2005; Park & Kim, 2016), suggest that the positive effects of teaching may not require a live audience to manifest themselves. Coleman et al. (1997) compared the effects of self-explanation to explaining the material to a peer without interacting with them; the results showed greater learning benefits for those who explained to a peer. Hoogerheide, Loyens, & van Gog (2014) compared the effects of explaining material on video versus writing explanations of the material to fictitious others, and found that those who created videos showed greater post-test performance, suggesting that it may be the act of verbal explanation that creates positive outcomes and that not necessarily any form of explanation will suffice.

Zavala and Kuhn (2017), however, found that writing dialogues of a debate between opposing candidate supporters in an election resulted in deeper understanding than writing an essay detailing the positions of the two candidates. This effect likely happens by giving the writing task a purpose and an imagined social interaction (Zavala & Kuhn, 2017). Constructing dialogues resulted in lower levels of absolutist epistemological beliefs and higher levels of evaluativist beliefs. The authors suggest that this solitary activity may take the place of actual social interaction and likely will show greater benefits than simply observing others' interactions.

Overall, teaching to computerized teachable agents has been shown to be effective as a learning tool (Biswas et al., 2005; Leelawong & Biswas, 2008; Holmes, 2007; Park & Kim, 2016). Biswas et al. (2005) use a teachable agent, Betty's Brain, in their study examining learning-by-teaching and self-regulation. Students teach Betty by creating concept maps which include key concepts and links between ideas. Betty is depicted as a face that can answer questions and explain what she knows, which will create the feeling of social interaction. In this experiment, Biswas et al. (2005) found that those who quizzed Betty included many more causal links in their concept maps, suggesting deeper understanding. They also found that having the agent encourage students to use self-regulated learning strategies increased transfer of learning.

Leelawong and Biswas (2008) found that those who taught the agent performed better than those who were taught by the agent. Additionally, those who taught the agent and received self-regulation aids had greater learning transfer, even after these self-regulation prompts were removed. Likewise, Chin et al. (2010) found that students teaching agents by creating concept maps demonstrated learning benefits that transferred to a different science topic area. The likely reason for this effect is that practicing with concept maps enhanced students' understanding of causal relationships (Chin et al., 2010). While students may not be explaining the material to a present other, these computerized agents do provide feedback to the student, creating a simulated interaction process and social presence. These agents also enhance learning by prompting, signaling, and focusing attention. Some teachable agents even show the agents' thought processes (Schwartz, Blair, Biswas, Leelawong, & Davis, 2007).

Utilizing teachable agents may even increase students' motivation to learn. For example, Chase, Chin, Oppezzo, and Schwartz (2009) found that those who believed they were teaching an agent spent more time studying and teaching and also learned more. Additionally, Park and Kim (2016) found that using a virtual tutor increased students' reading engagement and processing. The effectiveness of these teachable agents in enhancing knowledge challenge the idea that it is not only the verbal act of explanation that enhances knowledge, but rather, it may also be the sensation of social presence and interaction.

Herberg, Levin, and Saylor (2012), however, note that while the presence of others can enhance learning, actually teaching others can interfere with teacher learning, particularly when teachers use many highlighting behaviors, such as pointing. The authors suggest that a reason for this finding is that determining a tutee or agents' level of knowledge, and thus which information to spend more time explaining, can deplete cognitive resources. On the contrary, simply looking at the person or agent requires less cognitive resources. This finding provides support for the notion of enhancing teacher knowledge by generating explanations rather than interacting with a tutee.

Despite the effectiveness of these programs, Holmes (2007) cautions that pedagogical agents must strike a balance between facilitating learning and controlling learning, which may reduce students' self-regulation. Unfortunately, the research regarding pedagogical agents does not provide much clarity regarding the stages of the learning-by-teaching process, as the students are explaining to the agent (phase two) as well as interacting with and receiving feedback from them (phase three).

Phase three: Interaction. Some research suggests that teaching to a present other and interacting with them will be more efficacious than generating self-explanations. Roscoe and Chi (2007, 2008) contend that teacher-student interactions are a critical part of the process. Chi (2009) theorizes that interactive behaviors, such as engaging in dialogue and correcting others' errors, are more beneficial for learning than constructive and active activities. Constructive activities include concept mapping, self-monitoring, and asking questions, while active activities include highlighting and paraphrasing. It is possible that much of the positive effects of teaching in the peer tutoring literature may be due to these interactive processes.

Webb (1982) found that students frequently giving explanations to other students exhibited greater learning than those students who only rarely gave explanations, even when cognitive ability was controlled for. It has been suggested that the greater effects of actually teaching versus preparing to teach are dependent on the quality of questions asked and the explanations given (Duran, 2016; Roscoe & Chi, 2008; Webb, 1989), which students are often not skilled at providing (Roscoe & Chi, 2008). Okita & Schwartz (2013) found that recursive feedback, in which teachers observe their tutees' utilizing the newly learned information, resulted in greater teacher learning than those who did not receive this feedback. Because stage three of the learning-by-teaching process relies on the actions of the tutee, it is difficult to measure the effects of this stage. The present research will focus primarily on stages one and two in the process.

Teacher cognitive processes. An important factor to consider in the learning-by-teaching literature is the motivation of teachers, as disengaged teachers will likely not see great learning gains in their tutees or themselves. Benware and Deci (1984) examined the active versus passive mindsets of tutors and found that those expecting to teach reported more intrinsic motivation and showed better understanding of the material than those expecting to be tested. Fiorella and Mayer (2015) found that those expecting to teach reported more intrinsic motivation to learn the material and performed better on a comprehension test than those expecting a test. However, Renkl (1995) achieved opposite results, with those with a teaching expectancy reporting lower intrinsic motivation. This group also reported slightly higher levels of anxiety, which may serve as a mediator. These results may also have been the result of lower perceived competence and self-determination. Additionally, literature in this area has noted that extrinsic motivation, such as rewards, may hinder learning processes by reducing intrinsic motivation (McGraw, 1998).

Research in this area has also shown that self-regulation or self-monitoring is an important process to aid teacher learning. Self-regulation in learning concerns the choice of effective metacognitive strategies, positive self-efficacy, and monitoring of learning and goal progress (Zimmerman & Labuhn, 2012). A meta-analysis examining studies in which students were taught on self-regulated learning resulted in greater use of effective strategies, improved academic performance, and enhanced motivation (Dignath, Buettner, & Langfeldt, 2008). Furthermore, research has shown that generative learning activities, such as concept mapping, teaching, and self-explaining, can facilitate these processes (Fiorella & Mayer, 2015). For example, Coleman, Brown, and Rivkin (1997) found that those who generated explanations had greater learning gains than those who only summarized material.

Accurately assessing one's own comprehension, metacomprehension, has been shown to result in greater academic performance by identifying what material should be studied more (Nelson & Narens, 1994). However, metacomprehension accuracy in most research tends to be quite poor (Fukaya, 2010). For example, Fiorella and Mayer (2014) found that while those who expected to teach performed better on posttests than those expecting a test, they did not report significantly greater understanding of the material. Fukaya (2013) found that generating explanations can enhance metacomprehension accuracy. However, while it was found that those who actually generated explanations showed more metacomprehension accuracy than those who only expected to provide explanations, they surprisingly did not exhibit greater understanding of the material. Muis, Psaradellis, Chevrier, Di Leo, and Lajoie (2015) explored the use of concept maps and talking aloud while either preparing to teach or learning to learn and found that those who used more cognitive and metacognitive self-regulatory strategies, such as planning, assessing knowledge, and goal setting, developed better concept maps and subsequently performed better on the math task.

Roscoe and Chi (2007) found that tutors tend to engage in a knowledge-telling bias, in which they simply summarize the material without assessing one's knowledge.

They found that less tutors engage in knowledge-building, which entails engaging in deep processing of the information and using self-monitoring techniques. Roscoe and Chi (2008) later examined the effects of self-explanation, videoing an explanation, and explaining/interacting with a peer and found greater learning among the self-explainers. The authors found, however, that these results were likely due to the knowledge-telling bias. Analyzing the explanations and interactions revealed that those who engaged in reflective knowledge-building learned the most.

In 2014, Roscoe examined the learning effects of those who used self-monitoring, knowledge-telling, and knowledge-building. He found that those who engaged in more knowledge-building episodes did indeed learn more. The quality of tutee questions and comprehension assessments predicted the use of knowledge-building in tutors. There were also positive learning effects for students whose tutors engaged in more knowledge-building. He also suggested that deep questions asked by pupils can aid tutor's comprehension by forcing them to reflect on their own weaknesses with the material and provide novel examples or explanations. Roscoe (2014) concluded that knowledge-telling aids acquisition of rote knowledge, while knowledge-building helps enhance comprehension of the material. However, contrary to expectations, tutors did engage in adequate self-monitoring techniques but still exhibited strong knowledge-telling biases.

Students typically do not ask deep questions that aid teacher knowledge-building (Roscoe & Chi, 2008). Research has found that receiving training and scaffolding can aid students in engaging in knowledge-building and producing deep explanations (Coleman, 1998; King, 1994). Holmes (2007) utilized text and pedagogical agents to provide information and advice for generating effective explanations and self-monitoring to students. He found that those who received explanation resources and prompts from an agent and provided their explanations to the agent generated deeper explanations than those who received resources from text and then explained to a peer. Those who explained to the agent also generated deeper explanations than those who received resources and prompts from an agent but then explained to a peer. Those who collaborated with other students often ignored the agent's prompts and continued to ask shallow questions.

Additionally, cognitive ability, conscientiousness, or knowledge may affect the usefulness of learning-by-teaching. Chi et al. (1989) found that good students were more skilled at comprehension monitoring and generated better quality explanations than did poorer students. Pirolli and Recker (1994) found that increased self-monitoring and self-explanation can aid cognitive skill development; however, there does appear to be a limit of diminishing returns regarding self-explanations. Roscoe (2014) found that domain knowledge of tutors predicted the use of knowledge-building activities. More research is needed to determine the extent of generative learning techniques such as knowledge-building among those with various cognitive ability levels and with unfamiliar topics.

Summary. Overall, research has shown that teaching has potential to be a very powerful learning activity. From an examination of the literature, Fiorella and Mayer (2015) note that 17 out of 19 studies in which students who taught material to others performed better than those that did not, with an effect size of $d = 0.77$. Out of these 17 studies, learning was greatest when students also expected to teach, reflected on the material rather than simply summarizing, and engaged in interactions with others. However, there is still much uncertainty over whether it is the act of preparing to teach, generating explanations, or interacting with others that provides the greatest learning benefits for the teacher. Additionally, research in the learning-by-teaching literature has noted a need for examination of the cognitive mechanisms, such as self-regulation and metacomprehension, during the different phases of the process.

Concept mapping

A concept map is an arrangement of nodes (circles, ovals, or rectangles) that represent key concepts and lines that connect the nodes describing the key relationships among concepts (Fiorella & Mayer, 2015). Because concept maps are useful for describing hierarchical and causal relationships, they are popular for learning science processes. Much research in the learning fields on concept mapping has determined the usefulness of concept mapping in organizing cognitive information and assessing learning (e.g., Novak, 1998; Novak & Gowin, 1984; Williams, 1998). Concept maps can uncover students' misconceptions or missing knowledge about a topic (Novak & Gowin, 1984). Meta-analytic evidence shows that studying or creating concept maps can provide learning and transfer advantages over reading or participating in class (Nesbit & Adesope, 2006). The meta-analysis, however, included no experiments examining concept map creation that controlled for time spent with material.

The first uses of concept maps as a learning tool can be traced back to research by Novak and Gowin (1984). They attribute the effectiveness of concept mapping to Ausubel's (1963) theory of meaningful learning, in which individuals learn by integrating new knowledge to previously learned concepts. This is contrasted with rote learning, which is related to memorization or recall and may not become integrated into one's existing knowledge structure (Benware & Deci, 1984). Novak and Gowin (1984) also suggest that concept mapping can aid with meta-learning, or learning how to learn. Additionally, Redford, Thiede, Wiley, and Griffin (2012) found that creating concept maps can improve metacomprehension accuracy beyond both re-reading and studying an already created concept map. Metacomprehension accuracy among all groups was still quite low, but this improved in a second experiment in which students received information about the usefulness of concept mapping.

While research has shown that studying completed concept maps and using concept maps as supplementary educational tools can be beneficial, there is also evidence that the activity of creating concept maps aids learning. In a review of 25 experimental studies utilizing concept mapping and later comprehension or recall tests, Fiorella and Mayer (2015) found positive effects of concept mapping, versus either a different learning activity or only reading, with a moderate effect size ($d = 0.62$). Students who mapped performed better than non-mappers in 23 out of 25 of these studies.

Concept mapping has been shown to be even more beneficial for low-performing students (e.g., Haugwitz, Nesbit, & Sandmann, 2010; Liu, Chen, & Chang, 2010; Stensvold & Wilson, 1990). In their meta-analysis on concept mapping, Nesbit and Adesope (2006) reported an effect size of $d = 0.44$ for low verbal ability students versus $d = -0.33$ for high verbal ability students. Gathering evidence from the aforementioned 25 concept mapping studies, as well as 6 knowledge mapping experiments and 8 graphic organizer mapping experiments, Fiorella and Mayer (2015) note that mapping shows a stronger effect for lower-ability students ($d = 0.45$) than for higher-ability students ($d = -0.08$). Knowledge mapping and graphic organizer mapping are similar techniques to concept mapping in that they involve categorizations and linkages of ideas. For example, participants in Ausubel and Fitzgerald's (1962) study used advanced organizers, similar to graphic organizers, prior to reading a text on an unfamiliar subject. Those students in the lowest one-third of verbal ability levels showed significantly more learning and retention, measured by post-tests, than did the upper two-thirds of students by verbal ability. Similarly, Lambiotte and Dansereau (1992) suggested that students with low prior knowledge may benefit more from using maps than students with higher prior knowledge.

Roberts and Dansereau (2008) found that knowledge mapping yielded greater post-test scores than summarizing for an expository text about stress for lower verbal ability students, but not for higher verbal ability students. Additionally, personal relevance to the text predicted test scores for those who mapped. Lower verbal ability students who mapped reported more personal relevance to the text, while higher verbal ability students who only summarized reported more personal relevance to the text. Moreover, Liu et al. (2010) experimented with non-native English speaking college students who were trained in concept mapping and then read three English articles. The control group only read while the others completed concept maps after reading. Liu et al. (2010) found greater post-test performance for the mapping group among poor readers, but not among good readers.

One possible reason that low-achieving students benefit more from mapping is that low-ability students may be more easily distracted, and mapping requires focus and attention to the material (Stensvold & Wilson, 1990). Higher-ability students may prefer their typical study habits which have proven successful and which may even focus more on memorization than conceptual understanding (Stensvold & Wilson, 1990). Ausubel and Fitzgerald (1962) suggest that higher-ability students are more skilled at spontaneously organizing information cognitively, and thus do not benefit from the mapping exercises as much as lower-ability students do.

Fiorella and Mayer (2015) note that the positive effects of mapping may also depend on students receiving training on mapping. In Chang, Sung, and Chen (2002), students either read an expository text, received instruction on map creation, or both for several weeks. This study included four independent groups: one that corrected pre-made concept maps, a scaffolding group in which students completed incomplete maps with levels of assistance lessening over time, a map construction group, and a control group. The map correction group demonstrated the most improved reading comprehension. Additionally, the scaffolding approach was useful for enhancing summarizing abilities. Research has suggested that using map completion, map correction, or other scaffolding techniques may show greater benefits then map creation due to less cognitive overload (Katayama & Robinson, 2000). From an examination of the literature, Nesbit and Adesope (2006) note that preconstructed maps may be especially useful for students with lower verbal abilities.

Concept mapping is likely effective because it is a generative learning technique that requires students to identify and understand the main points of material, any processes that occur, *and* the relations among the key concepts (Fiorella & Mayer, 2015). Drawing concept maps is thought to mirror the mental organization processes occurring in students during learning. This is consistent with the Cognitive Theory of Multimedia Learning (Mayer, 2002), which states that meaningful learning involves selecting, organizing, and integrating material. With respect to mapping, selecting requires the learner to identify the information to include in the map. Organizing involves arranging the material in a way that makes sense to the student and shows the relationships among concepts, while integrating connects the new information with prior knowledge (Fiorella & Mayer, 2015). Moreover, concept mapping can possibly provide benefits beyond the topic one is using them for. Chin et al. (2010) found that using concept maps to teach an agent resulted in increased performance in a new subject area. This suggests that creating concept maps may enhance cognitive skills and strategies by providing a better understanding of causal relationships. Alternatively, creating concept maps may result in a better understanding of how to organize the information one knows or is learning.

Little research has combined the use of concept maps into studies examining processes occurring during different stages of the learning-by-teaching process. One notable study is that of Muis, Psaradellis, Chevrier, Di Leo, and Lajoie (2015), who found that those expecting to teach developed more accurate concept maps compared to those who only learned to learn, *and* they subsequently performed better on the task. In Biswas et al. (2005), students created concept maps as a means to teach a computerized agent, Betty, who encouraged students to use self-regulation strategies, such as asking another agent for help or setting goals. They found that adding the self-regulation tools increased learning beyond teaching Betty regularly. For example, Betty would suggest the student study a particular concept more, rather than telling them the exact changes to make to their concept maps. Biswas et. al (2005) also found that students who queried Betty, to determine what she has learned, produced more accurate concept maps. Additionally, Segedy, Kinnebrew, and Biswas (2013) found that having a pedagogical agent provide conversational feedback related to the students' goal of teaching Betty to create a correct map provided modest advantageous over the baseline agent system. Those receiving this feedback created higher quality maps.

In summary, concept mapping in its many forms has been shown to be an effective strategy for both assessing learning and as a generative learning technique. Like with generating explanations, it will likely be efficacious to provide training on how to create concept maps (Chang et al., 2002), as well as their usefulness (Redford et al., 2012), to students before asking students to create maps. It will also likely be advantageous to utilize incomplete maps or scaffolding approaches for those with little or no mapping experience. From an examination of concept mapping literature, Fiorella and Mayer (2015) note that the effectiveness of mapping may also depend on students' motivation and the clarity of the learning material. Past research has noted a need for experiments that further examine concept mapping and other self-monitoring tools as means to differentiate the cognitive processes of those preparing to teach, explaining, and teaching.

Purpose of the current study

While recent learning-by-teaching experiments have provided useful information, the evidence is not conclusive and there are limitations that need to be addressed. Much research in this field has suggested a need for examining the cognitive processes occurring during learning- by-teaching, as many learning-by-teaching studies do not attempt to measure cognitive processing. The present study combines the use of concept mapping into traditional learning-by-teaching experimentation to determine the extent to which generative processing has occurred. Specifically, this research utilizes a methodology and materials similar to that of Fiorella and Mayer's (2015) experiment two in which those in teaching conditions video record their explanations as if to show to a learner later.

The present study examines the comprehension test performance of participants in four conditions: testing, teaching, testing and completing a concept map, and teaching and completing a concept map. Examining the relevance and accuracy of the concept maps allows for conclusions of the cognitive organization occurring in those expecting different conditions. Research has also suggested a need to compare and contrast the various generative learning techniques. Fiorella and Mayer (2015) found across much research that mapping, self-explaining, and teaching are all effective learning techniques, with a slight advantage to teaching. The present study allows for comparisons among concept mappers, those explaining to a fictitious other, and those reading in preparation for a test.

The present research utilizes comprehension tests for all conditions before experimentation to assess prior knowledge, immediately after experimentation to assess learning, and after two to four weeks to assess retention. This is based on past research concluding that most forgetting occurs in about 30 days (Ebbinghaus, 1948; Murre & Dros, 2015), before flattening out. Therefore, if test scores are still high after this time period, it can be concluded that the students have retained the material. This also reduces the chances that the scores are a result of memorization or recall, but rather represent true understanding. The present research also allows for an examination of the 30-day forgetting curve, by comparing test scores for those with under and over a 30-day period between tests two and three. Based on research that has shown that concept mapping may be more beneficial for lower-ability students, particularly verbal ability (e.g., Liu, Chen,

& Chang, 2010; Nesbit & Adesope, 2006; Roberts & Dansereau, 2008; Stensvold & Wilson, 1990), the present study controls for students' reading abilities. Additionally, concept map accuracy, as indicated by students' concept map scores, and pre-test scores are controlled for when examining the last two comprehension tests.

It may be expected that participants' scores after four weeks will not be as high as the test immediately after the learning activity. Research has shown, however, that generative learning activities, such as concept mapping and explaining often best display learning effects after a time delay (Dunlosky et al., 2013; King, 1992; Roediger et al., 2006). Fiorella and Mayer's (2013; 2014) findings have supported this for teaching. For example, Fiorella and Mayer (2013) found that those expecting to teach had higher immediate test scores than those who actually taught, but on the delayed test, the teachers scored higher than those who only expected to teach. In their 2014 study, Fiorella and Mayer found an interaction between expectation and activity, such that those that expected to teach and did teach outperformed a control group, a group expecting to teach but not teaching, and a group expecting to test and then teaching. Because participants in the present study are expecting to teach and teaching, it is hypothesized that the effects of teaching will be significant on both the immediate and delayed tests.

Less research has examined knowledge retention from concept mapping over time delays. It is expected, however, that retention will be significant due to concept mapping being a generative learning activity. This leads to the following hypotheses.

Hypothesis 1. There will be a main effect of teaching on learning and retention scores.

Hypothesis 2. There will be a main effect of concept mapping on learning and retention scores.

Hypothesis 3. The main effect of teaching on learning will depend on the effect of concept mapping, such that the effect is stronger when a concept map is used and weaker when a concept map is not used.

Hypothesis 4. Those who teach will show more accurate and complete concept maps than those who do not teach.

CHAPTER II: METHODOLOGY

Participants

The participants for this study were recruited from fall 2017 Psychology undergraduate classes, including General Psychology, Social Psychology, and Introduction to Industrial-Organizational Psychology, at Middle Tennessee State University. These participants ranged in age from 18 to 46, with a median of 20. Participants were mostly Juniors and Sophomores (30% and 29% of the sample, respectively). Freshmen made up 23% of the sample, and seniors made up 9%. Students were offered extra credit from their instructors for participating in the study. The total sample size was 69 participants. Participants completed three comprehension tests: one before experimentation, one immediately after reading, concept mapping, and/or teaching, and one two to four weeks later. The researcher returned to the General Psychology class approximately four weeks after most students completed part one to conduct part two of the study. Those in the Social Psychology and Intro to Industrial-Organizational Psychology classes signed up for a time to complete part two of the study while at part one. Four out of the 69 participants did not return to complete the second part of the study.

Materials and Measures

The learning task in this study is the same text on the Doppler Effect as that used in Fiorella and Mayer (2014) and can be found in Appendix A. This text is about 600 words and includes illustrations. It is divided into four main parts. The text first provides an example of the effect as it would occur when a fire truck approaches then passes by someone. Next, a description is given of the characteristics of wavelength and frequency contributing to the effect. Then, an analogy is explained comparing the effect to a bug on a pond (e.g., what happens to the waves when the bug is stationary or moving). The last section of the text explains the logistics of the Doppler effect, including wavelength and frequency, in the fire truck example given previously. The comprehension test questions (Appendices B, C, and D) over the text and scoring rubric (Appendix E) are adapted from Fiorella and Mayer (2014). Three forms of the comprehension test were made to avoid testing effects.

Based on previous research (Chang et al. 2002; Katayama & Robinson, 2000) that has found that scaffolding techniques may prove beneficial for beginning mappers, the present study gave participants incomplete concept maps, with the number of concepts (blank nodes) specified, to complete. All connections between concepts appeared as blanks on the map that participants receive, but they were instructed to add any additional cross-links they believed were relevant. The map that participants received can be located in Appendix F. A complete version of the concept map was created from the reading text by the researcher. The map was created on the online software Cmap (© IHMC; see Appendix G). The concept map was reviewed and revised by the thesis committee, as well as a Physics graduate student, until it was deemed accurate, relevant, and complete. The concept map scoring rubric (Appendix H) was then created by the researcher based on the expert concept map.

For those in the teaching conditions, two Vivitar camcorders were placed on tripods in adjacent experiment rooms and turned on so that participants see a light on the device. The teaching conditions only had one or two participants in each session so that participants could record their lectures at the same time in different rooms. The camcorder did not actually record participants teaching as their lectures are not needed for the study. Participants were told they are being recorded so as to increase their motivation and effort for the task.

Participants in all conditions completed a post-experimental survey after the comprehension test in phase 2 of the study. This survey (Appendix I) was developed by the researcher and measures previous experience with the Doppler effect and concept mapping, participants' metacomprehension during the task, their enjoyment of the experiment and learning methods, their motivation during the task, and anxiety levels. Demographic questions asked on the survey included GPA, year in school, major, and age. Participants in all conditions were given ID numbers in the first phase of the study that were written on their concept map, comprehension test, and all surveys, as a means to match participant data.

The faculty advisor for this study obtained participants' reading ACT scores from the university database. The ACT has been shown to be correlated with general cognitive ability (Koenig, Frey, & Detterman, 2008). The reading section of the ACT has also been shown to measure students' understanding of complex texts, which predicted college success in courses with higher reading demands (Allen, Bolender, Fang, Li, & Thompson, 2016). Additionally, the texts included in the ACT reading section are similar in length and complexity to the Doppler effect text used in the study. This measure of reading ability served as a control in the analyses.

Procedure

Before data collection began, approval for the study was given by the Institutional Review Board at Middle Tennessee State University. The approval form can be found in

Appendix J. Prior to students signing up to participate in the study, two faculty advisors for this research provided concept mapping training to entire sections of General Psychology and Social Psychology. Concept mapping was incorporated into the classes' curriculums for the semester, and students were not aware of the opportunity to sign up for the study. The training lasted 25 minutes and described the logistics of concept mapping and how to create maps, including an example demonstration of completing a concept map (Appendix K). This training utilized ideas from Novak (1998) and Salmon and Kelly (2015). Students were given additional information about concept mapping to take with them (Appendix L). Approximately two weeks after the trainings, students in these two classes were informed by their instructors of the extra credit opportunity of participating in this study. A sign-up sheet for the study with time slots was given to students in the two classes to sign up for the experiment. Students from the Introduction to Industrial-Organizational Psychology course were recruited as a secondary source of participants and thus did not receive concept mapping training. Therefore, prior concept mapping experience and presence at a concept mapping training session were examined for group differences in map scores.

In the experimental study, participants in all conditions first read and signed a consent form describing the research study to indicate their willingness to participate in the study. Participants were randomly assigned to one of four conditions: testing (Condition 1), teaching (Condition 2), concept mapping (Condition 3), and concept mapping and teaching (Condition 4). Because past research (Fiorella & Mayer, 2014) has shown that learning benefits are greatest when participants both expect to teach and actually teach, compared to expecting to teach and testing or expecting to test and then actually teaching, the present study kept participants' expectations consistent with the activity they would be performing. The researcher then explained the tasks the participants would be participating in, which differed for each condition. These instructions can be found in Appendix M. All participants then completed a pre-comprehension test (Appendix B).

All conditions spent 25 minutes total time interacting with the material, whether it was reading, teaching, or concept mapping. The teaching and concept mapping activities are more generative learning strategies, which are hypothesized to lead to greater learning and retention than only reading. Participants in all conditions were instructed that they were allowed to take notes on the lesson itself or on a blank sheet of paper that would be provided to them, although they would not be permitted to use the notes while teaching, concept mapping, or taking the comprehension test. After participants completed their learning activities, they were given 10 minutes to take the comprehension test (Appendix C).

Participants in the test-only condition (Condition 1) were given 25 minutes to read and study the material. They then completed the comprehension test (Appendix C). Participants were then told they were finished and were thanked for their time.

Participants in the teaching condition (Condition 2) were given 20 minutes to read and study the material. Teachers were secluded when giving their lesson. Participants were instructed to explain the learning material as if it were a 'how-to' video they would show to their peers to teach them the material. They were given up to 5 minutes to give their lecture and were instructed to return to the room the researcher was in when they finished. Participants then took the comprehension test (Appendix C) and were then told they were finished and were thanked for their time.

Participants in the concept mapping group (Condition 3) were given 15 minutes to read and study the text. Then, participants were given 10 minutes to complete the concept map (Appendix G). They then completed the comprehension test (Appendix C). Participants were then told they were finished and were thanked for their time.

Finally, participants in the teach and concept map group (Condition 4) were given 10 minutes to read and study the lesson. Participants were then given 10 minutes to complete the concept map. They then had up to 5 minutes to record their lecture. As in condition one, they were secluded when they gave their lesson and were instructed to return to the room the researcher was in when they finished. They then took the comprehension test (Appendix C). Participants were then told they were finished and were thanked for their time.

After two to four weeks, the participants from part one in the study returned to complete the second phase of the study. Participants completed a different form of the same comprehension tests they completed at the beginning of the study and immediately after the experiment (Appendix D). Participants were then given the post-experimental survey (Appendix I). Participants were then debriefed about the purpose of the study and the various conditions included in the study. Participants were informed that those in the teaching conditions were not actually being recorded. They were then thanked for their time and participation in the study.

CHAPTER III: RESULTS

Preliminary Analyses

The total sample size was 69 participants, with n = 19 in condition one, n = 17 in condition two, n = 17 in condition three, and n = 16 in condition four. Four participants did not return to the second part of the study and thus do not have test scores for test three or items from the demographic questionnaire. Three of these participants were in condition one and one participant was in condition four. ACT Reading scores were obtained by the faculty advisor for this study through the university database. ACT scores were unavailable for some students, so scores were collected for 57 of the 69 participants.

After data collection, the researcher scored the comprehension tests and concept maps using the rubrics. Demographic information was coded as specified in Appendix I. Participants' scores and demographic information was entered in Microsoft Excel and then imported into SPSS, where all data analysis took place. A two-tailed alpha level of $\alpha = .05$ was used for all analyses.

Table 1 shows the descriptive statistics for the three comprehension tests and concept maps. Each test had the same ten items and answer choices, but in a different form. The minimum and maximum possible test scores were -12 to 12. Participants received one point for every correct answer and were given -1 point for every incorrect answer. Concept maps had a possible score range of 0 to 21. Participants were given 1 point for every correct fill-in-the-blank, 0 points for each incorrect or empty blank, 2 points for each correct cross-link drawn, and 0 points for each incorrect cross-link drawn. See Appendices B through H for the comprehension tests, concept maps, and rubrics.

Table 1
Descriptive statistics for comprehension tests and concept maps

	n	Minimum	Maximum	*M*	*SD*
Test 1	69	-6	8	2.57	3.220
Test 2	69	-4	12	5.87	3.063
Test 3	65	-4	10	4.26	3.654
Concept Map	33	2	16	8.15	2.60

To determine reliabilities for each of the three comprehension tests, answer choices were coded as correct, incorrect, or partially correct, as 1, 2, and 3, respectively. This method of coding was chosen because the tests were *select all that apply*, so some questions had as many as 9 combinations of answers. The reliability coefficients for each of the 3 tests is summarized in Table 2 below.

Table 2
Cronbach's Alpha for 3 comprehension tests

	Number of items	Coefficient α
Test 1	10	0.51
Test 2	10	0.60
Test 3	10	0.59

Primary Analyses

Hypothesis 1 stated that there would be a main effect of teaching on learning and retention scores. Hypothesis 2 stated that there would be a main effect of concept mapping on learning and retention scores. Further, Hypothesis 3 predicted there would be a significant interaction between teaching and concept mapping on learning and retention scores. For these hypotheses, two 2x2 ANCOVA's were conducted, with Reading ACT scores and comprehension tests one and two entered as controls. Specifically, one 2x2 ANCOVA measured immediate learning (test 2 scores), with test 1 scores and ACT reading scores serving as controls. The other 2x2 ANCOVA measured retention (test 3 scores), with test 2 scores and ACT reading scores serving as controls. Concept mapping condition (mapping or no mapping) and teaching condition (teaching or no teaching) served as between-subjects factors. The main effects of both concept mapping and teaching on comprehension test scores were examined, as well as the interaction between the two.

The SPSS mixed procedure was used to conduct the ANCOVA's with unequal population variances. First, the relationships between all covariates and dependent variables were explored using polynomial regression. For the relationship between ACT reading scores and comprehension test 2 scores, the linear test was significant, $t\ (54) = 4.29$, $p < .001$, but the quadratic test was not, $t\ (54) = -1.37$, $p = .18$. Therefore, ACT reading scores were included in the linear form in the subsequent analyses. The relationship between ACT reading scores and comprehension test 3 scores was also explored via polynomial regression. The linear test was significant, $t\ (51) = 3.75$, $p < .001$, but the quadratic test was not, $t\ (51) = -2.10$, $p = .04$. For the relationship between test 1 scores and test 2 scores, the linear test also was significant, t (66) = 5.07, $p < .001$, but the quadratic test was not, t (66) = .70, $p = .49$. Likewise, in the relationship between test 2 scores and test 3 scores, the linear test was significant, t (62) = 4.75, $p < .001$, but the quadratic test was not, t (62) = -1.18, $p = .24$.

Tests for homogenous slopes indicated the relationship between test 2 scores and ACT reading scores, F (3, 19.78) = 1.31, $p = .29$ did not differ by condition. The relationship between test 2 scores and test 1 scores, F (3, 22.71) = 4.87 differed by condition. An additional test for homogenous slopes indicated that the relationship between ACT reading scores and test 3 scores did differ by condition, F (3, 17.19) = 6.44, $p < .05$. Finally, the relationship between test 3 scores and test 2 scores did not differ by condition, F (3, 16.35) = 3.19, $p = .051$.

Because the sample sizes in each condition were unequal, the SPSS mixed procedure was used to conduct the 2x2 ANCOVA's. The 2x2 ANCOVA measuring the interaction between mapping and teaching, controlling for ACT reading scores and test 1 scores, to measure learning (test 2 scores) was not significant, F (1, 48.49) = 2.80, $p = .10$, $\omega^2 = -.01$. Neither the main effects for mapping, F (1, 48.49) = 0.57, $p = .46$, $\omega^2 = -.02$, nor teaching, F (1, 48.49) = 0.30, $p = .586$, $\omega^2 = -.01$, were significant. The 2x2 ANCOVA measuring the interaction between mapping and teaching, controlling for ACT reading scores and test 2 scores, to measure retention (test 3 scores) was not significant, F (1, 48.49) = 0.45, $p = .51$, $\omega^2 = -.03$. Neither the main effects for mapping, F (1, 48.49) = 4.00, $p = .051$, $\omega^2 = -.02$, nor teaching, F (1, 48.49) = 1.33, $p = .254$, $\omega^2 = -.02$, were significant. None of the Sidak pairwise comparisons for the above analyses indicated significant differences between groups. Hypotheses 1, 2, and 3 were, therefore, not supported. See table 3 for descriptive statistics from these analyses.

Table 3
Descriptive statistics for test scores controlling for ACTR and Test 1

				95% *CI*	
Condition	Test	*N*	*M*	Lower Bound	Upper Bound
Control	Test 2	15	6.22	4.98	7.47
	Test 3	13	3.46	1.34	4.67
Teaching	Test 2	13	6.34	5.36	7.31
	Test 3	13	4.73	3.38	6.08
Mapping	Test 2	15	6.26	5.37	7.16
	Test 3	15	5.13	3.83	6.44
Teaching*Mapping	Test 2	14	7.14	6.06	8.23
	Test 3	13	6.00	4.14	7.86

Because there was missing data for ACT reading scores (for 12 out of 69 participants), and because the sample size is small, factorial ANOVA's also were run as an exploratory analysis. Neither the main effects of teaching, F (1, 59.29) = 1.24, p = .27, ω^2 = .003, nor mapping, F (1, 59.29) = 0 .003, p = .96, ω^2 = -.01, were significantly related to test two scores without the covariates. The interaction between teaching and mapping was not significant, F (1, 59.29) = 1.12, p = .295, ω^2 = .00. Likewise, neither the main effects of teaching, F (1, 58.95) = 3.30, p = .075, ω^2 = .03, nor mapping, F (1, 58.95) = 3.06, $p = .085$, $\omega^2 = .03$, were significantly related to test three scores without the covariates. The interaction between teaching and mapping for test three scores was not significant, F (1, 58.95) = 0.11, $p = .74$, $\omega^2 = -.01$. See table 4 for descriptive statistics.

Table 4
Descriptive statistics for test scores

				95% *CI*	
Condition	Test	*n*	*M*	Lower Bound	Upper Bound
Control	Test 2	19	5.81	3.96	7.72
	Test 3	16	3.46	1.13	5.62
Teaching	Test 2	17	6.29	5.44	7.13
	Test 3	17	5.09	3.90	6.27
Mapping	Test 2	17	5.90	4.94	6.87
	Test 3	17	5.06	3.75	6.37
Teaching*Mapping	Test 2	16	6.69	5.54	7.83
	Test 3	15	6.00	4.37	7.64

Hypothesis 4 stated that those who taught would show more accurate concept maps than those who did not teach. This was measured with a Welch ANOVA due to the unequal sample sizes of those who taught and did not teach. It was found that concept map scores differed by teaching condition, F (1, 27.96) = 4.80, $p = .037$, $\omega^2 = .11$. This hypothesis was supported. See table 5 for descriptive statistics.

Table 5
Descriptive statistics for concept maps

Condition	*N*	Minimum	Maximum	*M*	*SD*
Teaching	16	6	16	9.13	2.78
No Teaching	17	2	9	7.24	2.11

Supplementary Analyses

Additionally, this study sought to further clarify the learning curve by comparing differences in retention among those with different time periods in between tests. Those with under and over a 28-day period in between tests two and three were compared via an independent samples *t* test. The difference in test 3 scores for those equal to or over 28 days (*M* = 4.16, *SD* = 4.08, *n* = 25), and those under 28 days (*M* = 4.33, *SD* = 3.42, *n* = 40), was not significant, *t* = -.055, *p* = .957, *d* = -.005.

Other demographic characteristics also were explored in relation to test score differences. Regarding metacomprehension accuracy, those who reported positively "I feel that I performed well on the comprehension tests," (*n* = 33), significantly outscored those who did not, (*n* = 11), on both test two, *F* (4, 59) = 4.71, *p* = .002 ω^2 = .19, and test three, *F* (4, 59) = 3.49, *p* = .013, ω^2 = .14. Those who reported positively to "I felt that I understood the learning material on the Doppler effect," (*n* = 42), significantly outscored those who did not, (*n* = 12), on test three, *F* (3, 60) = 5.00, *p* = .004, ω^2 = .20.

Having prior concept mapping experience did not significantly predict scores on the comprehension tests or on the concept map score. See table 6 for these statistics.

Additionally, there were no significant group differences on test scores by GPA. These analyses are summarized in table 7.

Table 6
One-way ANOVA for concept map experience differences

Dependent Variable	*Df*	*MSE*	*F*	*P*
Test 1	1	0.69	0.06	.80
Test 2	1	0.03	0.03	.87
Test 3	1	49.11	3.84	.05
CMAP Score	1	1.75	0.25	.62

Table 7
One-way ANOVA for GPA differences

Dependent Variable	*df*	*MSE*	*F*	*P*
Test 1	4	18.58	1.86	.13
Test 2	4	10.18	1.05	.39
Test 3	4	31.00	2.51	.05

CHAPTER IV: DISCUSSION

Summary of Findings

The purpose of the current research was to examine via concept maps the cognitive organization that was taking place while preparing to teach. Adding concept maps to the process also allows for generative learning that can therefore enhance the quality of teaching. Hypotheses 1, 2, and 3 were not supported. There were no main effects for teaching or mapping on learning or retention scores. The interactions between teaching and mapping also were not significant for learning or retention. Additionally, none of the post-hoc pairwise analyses were significant. Hypothesis 4, which stated that those who taught would score higher on concept maps than those who did not teach, was supported.

There are several possible reasons for the lack of significance for Hypotheses 1-3. First, the sample size was small, which may not have allowed for an effect to be detected. Additionally, as this experiment was not related to students' grades or other personal outcomes, participants may not have been motivated to learn the material and put effort into the tests, lessons, and concept maps. Participants' self-reported motivation to learn the material, interest of the material, and enjoyment of the experiment (from the post-survey) were analyzed to determine group differences relating to test scores, but no significance was found. It is also possible that the concept maps in the current study were not challenging enough, as they were fill-in-the-blank. There was a lack of variance in concept map scores; 25 of the 33 mappers had scores between 7 and 9, although the possible range was 0 to 21.

It is important to note that the 2x2 ANCOVA controlling for ACT Reading scores and Test 2 scores, relating to retention scores, approached significance with a *p* value of .051. It is possible that a study with greater power would have achieved statistically significant results. Additionally, this provides a reason to continue this avenue of research. This ANCOVA did show a larger effect than the ANCOVA measuring test two score differences, which was consistent with past research from Fiorella and Mayer (2014) in which the generative learning activity of teaching was more prevalent after time delays.

The significance of Hypothesis 4 can have great implications. This suggests that there is a learning advantage when preparing to teach, as shown by the increase in concept map scores. As consistent with past research, it appears that preparing to teach can provide benefits as great as, or even greater than, those of actually teaching. It cannot, however, be determined whether this increase is due to increased motivation, fear of appearing uninformed on video, the activity of mapping, or other factors.

Limitations and Future Directions

While yielding important insights, the present study has a number of limitations. First, the sample size was small. Time and space requirements did not allow for a large number of participants to be run. Attrition is also a factor when completing two-part studies. Additionally, there was a range of length of time in between tests two and three due to scheduling and time limitations. It did appear that retention scores decreased as time in between tests increased, however, which is an interesting finding. While past research has shown that generative learning is most prevalent after time delays, it appears that there is a limit to these delays, as shown in research on forgetting curves (Murre &

Dros, 2015). Another limitation of the present study is that several participants expressed discomfort with being recorded. They were thus placed into either condition 1 or 3 so that they were not recorded. This resulted in less participants in conditions 2 and 4, although sample sizes remained fairly equal.

As previously mentioned, there was not much variation in concept map scores. This could be due to the fill-in-the-blank map not being challenging enough. It is still likely, however, that creating a map from scratch would have been too challenging for these lower-classmen college students with little concept mapping experience. Additionally, prior concept mapping experience did not significantly affect concept map scores. Future research should examine different levels of scaffolding to determine how much aid will best benefit students of this level.

Additionally, the reliabilities for the three comprehension tests were fairly low according to common psychological standards. This could have resulted in inadequate measures of true learning and retention. It is also possible that some questions were too difficult. In particular, the question "Imagine a sound source is moving towards a stationary observer. How does the observer perceive the sound at the exact moment when the source crosses paths with the observer?" received less than 30% accurate answers on each test. The correct answer was that the observer will not perceive a difference in pitch, with the other two answers being a perceived higher or lower pitch. All other questions had more normal distribution levels of correct, incorrect, or partially correct answers. Another possible reason for the lack of sufficient reliability is that many test-takers did not choose more than one answer for the questions with two correct answers, even though both verbal and written instructions were given to *select all that apply*.

The present study did not examine the content of the videos, nor has much research using this methodology. Future research could examine this as a way to gain a more complete picture of the cognitive effects occurring for the various expectations. As past research (Roscoe & Chi, 2008) has suggested, learning benefits may be greater for those who engage in knowledge-building rather than those who exhibit a knowledge-telling bias, in which their explanations do not go beyond summarization. Examining video content would be especially insightful in a study incorporating concept mapping to determine any increase in teaching quality due to increased understanding of the material. Much research on learning-by-teaching has used education students as participants. It can be assumed that education students will be more skilled at teaching than the general population. This therefore may provide an avenue to determine if learning-by-teaching is more effective for those who are good teachers and provide effective lessons.

As Fiorella and Mayer (2014) and Nestojko et al. (2014) suggest, future studies should also examine learning effects when using extremely disorganized or more complex lessons to better infer cognitive organization processes. The lesson in the present study was outlined with headings and included visual representations. The text was fairly short and simple. This may have caused participants to revert to attempting to memorize the text content rather than understanding the main ideas. It would be interesting to examine the effects of preparing to teach with longer, more disorganized learning content.

Further, now that it seems research has found that both preparing to teach and generating explanations are more efficacious than learning to learn or preparing for a test, the effects of explaining to oneself or fictitious others should be compared to those actually interacting with others while teaching. In other words, since phase two (explaining) and phase one (preparing) have been examined, research should now compare phase two to phase three (interacting). This realm of research can have great implications. If the mechanism for the process' effectiveness occurs simply from the act of verbal explanation or the social presence of a fictitious other, applying the method in educational settings will be much more realistic than having students actually tutor each other. In general, however, research on interacting with others while teaching have shown positive effects, such as in the peer tutoring literature. One reason for this is that the teacher is increasing his/her metacomprehension through interaction (Roscoe & Chi, 2008).

Conclusion

Both learning-by-teaching and concept mapping have displayed their merit for use as learning activities, though still not fully understood. This research provided greater insight into these processes by examining the cognitive organization occurring when preparing to teach via concept maps. Though the main effects of mapping and teaching and the interactions between them were not significant, this avenue of research shows promising potential to explore. The increased concept map scores of those preparing to teach in the current study especially suggests that the process of preparing to teach can provide great benefits. Since both preparing to teach and concept mapping have been shown separately to increase learning, it is intuitive that the two used together would provide even greater benefits. The limitations of the current study may have prohibited these benefits from appearing.

A limitation to applying this framework in other settings is that mapping may not be beneficial for all learning topics. Most of the research on mapping has used science texts. Research should thus be conducted on using mapping for other school subjects, and even outside of educational settings. Further, the learning-by-teaching method should be utilized in various settings, including as formal parts of educational programs and in on-the-job training programs in organizations. Though more research is needed, learning-by-teaching and concept mapping show great potential for deeper learning, which can have positive implications in a variety of applied settings.

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APPENDICES

APPENDIX A: DOPPLER EFFECT TEXT

The Doppler Effect

Background

Almost everyone has experienced the Doppler Effect, though perhaps without knowing what caused it. For example, imagine you are standing on a street corner as a fire truck approaches with its siren blaring. The perceived pitch of the siren will sound higher as it comes closer to you. Then, as it passes by, the pitch will sound lower. This is one of many examples of the Doppler Effect: the change in how sounds are perceived due to movement.

Sound waves

Why does this change occur? Movement changes the way different characteristics of sound waves are perceived, and therefore, how the sound is perceived. Sound waves have two primary characteristics: frequency and wavelength. As we will see, movement causes changes in how we perceive the frequency and length of sound waves, which ultimately impact how we perceive the sound. First, let’s briefly go over each of these characteristics.

Wave frequency

Wave frequency refers to the number of waves passing through a given point during one second. It corresponds to how we perceive the pitch of a sound: if waves occur at a high frequency, they will produce a high pitch; if waves occur at a low frequency, they will produce a low pitch. For example, the cry of a baby has a relatively high pitch, while the sound of thunder has a relatively low pitch. The reason these two sounds are perceived differently is because they have different wave frequencies. Figs. 1 and 2 illustrate the difference between low and high frequency sound waves.

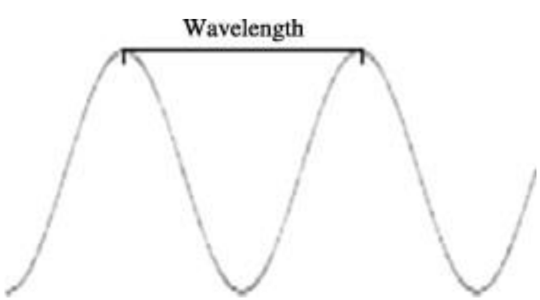


Fig. 1. Low frequency sound waves.

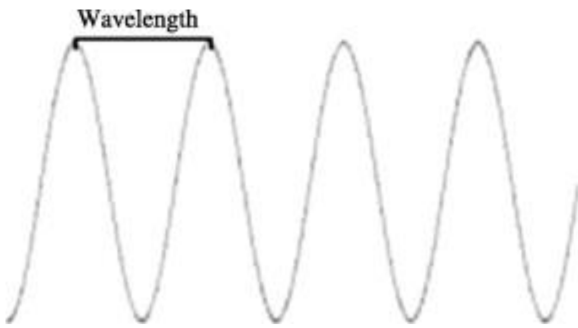


Fig. 2. High frequency sound waves.

Wavelength

Closely related to wave frequency is wavelength. Wavelength refers to the distance between adjacent waves (see figures above). As you might expect, longer waves require more time to travel a given distance than shorter waves. Consequently, longer sound waves have a lower frequency and a lower pitch. On the other hand, short sound waves have a higher frequency and higher pitch.

How the Doppler Effect works

The Doppler Effect is about how movement influences how the frequency and length of sound waves are perceived. To illustrate this, imagine a bug jiggling on the surface of a pond. If the bug is stationary, the waves on the surface of the water around it will be at the same frequency and length in all directions, as in Fig. 3. Now suppose that the bug begins moving to the right. The waves it produces become shorter and more frequent to the right of the bug and longer and less frequent to the left of the bug, as shown in Fig. 4.

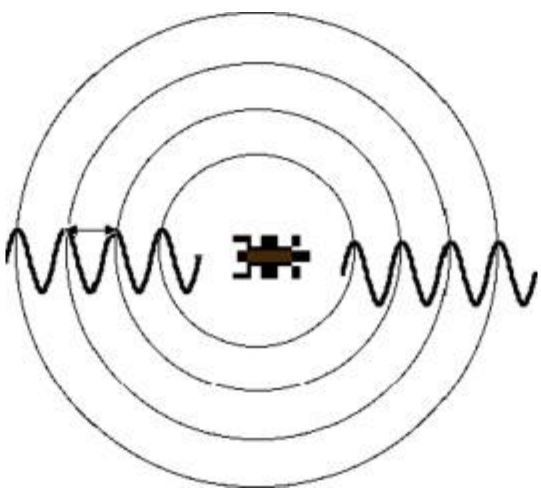


Fig. 3. Stationary bug.

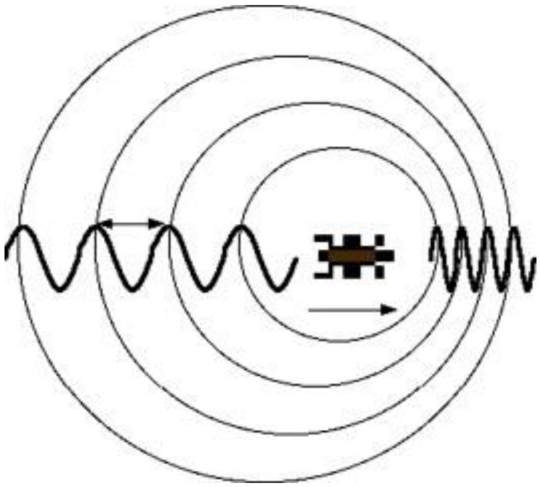


Fig. 4. Bug moving to the right.

Now let's relate the bug example to how the Doppler Effect occurs in sound waves. Imagine again that a fire truck is approaching with its siren blaring, as illustrated in Fig. 5. As the fire truck approaches, the sound waves between the fire truck and the girl become shorter and more frequent, resulting in a higher perceived pitch. As the ambulance drives by, the sound waves between the fire truck and the girl are longer and less frequent. As a result, the girl perceives the pitch as getting lower. This is because the movement of the fire truck causes changes in how the sound is perceived. This influence of movement on perceived sound is the core principle of the Doppler Effect.

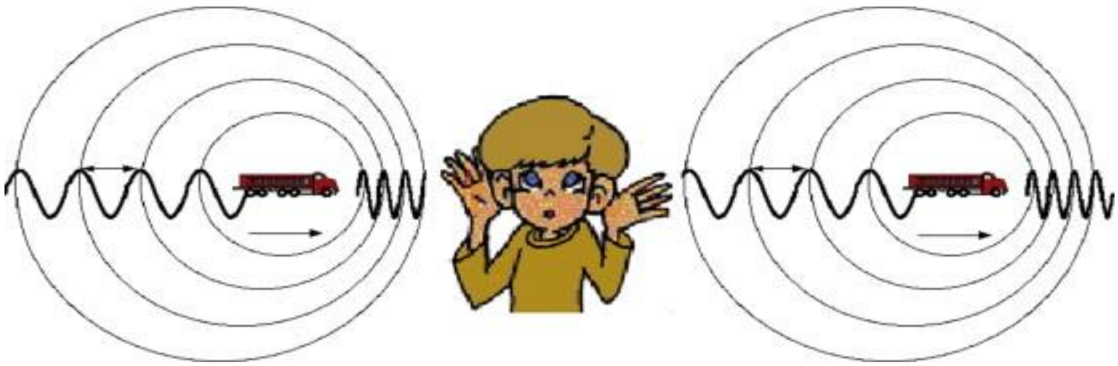


Fig. 5. The Doppler Effect of sound waves.

APPENDIX B: COMPREHENSION TEST 1

Please choose the correct answer(s). Select all that apply.

1. Longer sound waves result in:
   A. A perceived high pitch
   B. A perceived low pitch
   C. No perceived pitch

2. The number of waves passing through a point during one second refers to:
   A. Wave frequency
   B. Sound waves
   C. Wavelength
   D. Pitch

3. Waves occurring at a low frequency will result in:
   A. A perceived high pitch
   B. A perceived low pitch
   C. No perceived pitch

4. As a sound source moves towards an observer, the sound waves between the source and the observer:
   A. Increase in frequency (the waves become more frequent)
   B. Decrease in frequency (the waves become less frequent)
   C. Increase in wavelength (the waves get longer)
   D. Decrease in wavelength (the waves get shorter)

5. As a sound source moves away from an observer, the sound waves between the source and the observer:
   A. Increase in frequency (the waves become more frequent)
   B. Decrease in frequency (the waves become less frequent)
   C. Increase in wavelength (the waves get longer)
   D. Decrease in wavelength (the waves get shorter)

6. Imagine a fire truck with its siren blaring is approaching an observer standing on a street corner. In this scenario, what would intensify the Doppler Effect?
   A. Increase the speed of the fire truck
   B. Decrease the speed of the fire truck
   C. Have the observer move farther from the fire truck

7. Imagine a fire truck is driving down the road with its siren blaring. An observer is in a car moving in the same direction and at the same speed of the truck. They are able to hear the siren. Would the observer experience the Doppler effect?
   A. Yes, because there is a change in frequency and wavelength.
   B. Yes, because there is a change in frequency.
   C. No, because there is no change in frequency or wavelength.
   D. No, because there is only a change in frequency.

8. Imagine a fire truck is driving down the road with its siren blaring. How does the truck's motion influence the way the driver experiences the sound of the siren?
   A. It would not influence the driver's experience of the siren (there would be no Doppler Effect).
   B. They would perceive a higher pitch.
   C. They would perceive a lower pitch.

9. Would the Doppler Effect occur if an observer was to move towards a stationary sound source?
   A. Yes, because the sound waves would reach the observer more frequently. The wavelengths would get longer, and the perception of pitch would decrease.
   B. Yes, because the sound waves would reach the observer more frequently. The wavelengths would get shorter, and the perception of pitch would increase.
   C. No, because the sound waves will not change length.
   D. No, because the sound waves will not change frequency.

10. Imagine a sound source is moving towards a stationary observer. How does the observer perceive the sound at the exact moment when the source crosses paths with the observer?
   A. The observer will perceive a higher pitch.
   B. The observer will perceive a lower pitch.
   C. The observer will not perceive a difference in pitch.

APPENDIX C: COMPREHENSION TEST 2

Please choose the correct answer(s). Select all that apply.

1. The number of waves passing through a point during one second refers to:
   A. Pitch
   B. Wave frequency
   C. Wavelength
   D. Sound waves

2. Waves occurring at a low frequency will result in:
   A. A perceived low pitch
   B. A perceived high pitch
   C. No perceived pitch

3. Longer sound waves result in:
   A. A perceived low pitch
   B. A perceived high pitch
   C. No perceived pitch

4. Imagine a fire truck with its siren blaring is moving towards an observer standing on a street corner. In this scenario, what would intensify the Doppler Effect?
   A. Decrease the speed of the fire truck
   B. Increase the speed of the fire truck
   C. Have the observer move farther from the fire truck

5. Imagine a sound source is moving towards a stationary observer. How does the observer perceive the sound at the exact moment when the source crosses paths with the observer?
   A. The observer will perceive a lower pitch.
   B. The observer will perceive a higher pitch.
   C. The observer will not perceive a difference in pitch.

6. As a sound source moves away from an observer, the sound waves between the source and the observer:
   A. Decrease in wavelength (the waves get shorter)
   B. Decrease in frequency (the waves become less frequent)
   C. Increase in wavelength (the waves get longer)
   D. Increase in frequency (the waves become more frequent)

7. As a sound source moves towards an observer, the sound waves between the source and the observer:
   A. Increase in wavelength (the waves get longer)
   B. Increase in frequency (the waves become more frequent)
   C. Decrease in frequency (the waves become less frequent)
   D. Decrease in wavelength (the waves get shorter)

8. Imagine a fire truck is driving down the road with its siren blaring. An observer is in a car moving in the same direction and at the same speed of the truck. They are able to hear the siren. Would the observer experience the Doppler effect?
   A. No, because there is only a change in frequency.
   B. No, because there is no change in frequency or wavelength.
   C. Yes, because there is a change in frequency.
   D. Yes, because there is a change in frequency and wavelength.

9. Would the Doppler Effect occur if an observer was to move towards a stationary sound source?
   A. No, because the sound waves will not change frequency.
   B. No, because the sound waves will not change length.
   C. Yes, because the sound waves would reach the observer more frequently. The wavelengths would get shorter, and the perception of pitch would increase.
   D. Yes, because the sound waves would reach the observer more frequently. The wavelengths would get longer, and the perception of pitch would decrease.

10. Imagine a fire truck is driving down the road with its siren blaring. How does the truck's motion influence the way the driver experiences the sound of the siren?
    A. They would perceive a lower pitch.
    B. They would perceive a higher pitch.
    C. It would not influence the driver's experience of the siren (there would be no Doppler Effect).

APPENDIX D: COMPREHENSION TEST 3

Please choose the correct answer(s). Select all that apply.

1. Waves occurring at a low frequency will result in:
   A. No perceived pitch
   B. A perceived high pitch
   C. A perceived low pitch

2. Longer sound waves result in:
   A. No perceived pitch
   B. A perceived high pitch
   C. A perceived low pitch

3. The number of waves passing through a point during one second refers to:
   A. Sound waves
   B. Pitch
   C. Wavelength
   D. Wave frequency

4. Imagine a fire truck is driving down the road with its siren blaring. An observer is in a car moving in the same direction and at the same speed of the truck. They are able to hear the siren. Would the observer experience the Doppler effect?
   A. No, because there is no change in frequency or wavelength.
   B. No, because there is only a change in frequency.
   C. Yes, because there is a change in frequency and wavelength.
   D. Yes, because there is a change in frequency.

5. Would the Doppler Effect occur if an observer was to move towards a stationary sound source?
   A. No, because the sound waves will not change length.
   B. No, because the sound waves will not change frequency.
   C. Yes, because the sound waves would reach the observer more frequently. The wavelengths would get longer, and the perception of pitch would decrease.
   D. Yes, because the sound waves would reach the observer more frequently. The wavelengths would get shorter, and the perception of pitch would increase.

6. Imagine a fire truck is driving down the road with its siren blaring. How does the truck's motion influence the way the driver experiences the sound of the siren?
   A. They would perceive a higher pitch.
   B. They would perceive a lower pitch.
   C. It would not influence the driver's experience of the siren (there would be no Doppler Effect).

7. Imagine a sound source is moving towards a stationary observer. How does the observer perceive the sound at the exact moment when the source crosses paths with the observer?
   A. The observer will not perceive a difference in pitch.
   B. The observer will perceive a higher pitch.
   C. The observer will perceive a lower pitch.

8. As a sound source moves towards an observer, the sound waves between the source and the observer:
   E. Increase in frequency (the waves become more frequent)
   F. Increase in wavelength (the waves get longer)
   G. Decrease in frequency (the waves become less frequent)
   H. Decrease in wavelength (the waves get shorter)

9. As a sound source moves away from an observer, the sound waves between the source and the observer:
   A. Increase in frequency (the waves become more frequent)
   B. Increase in wavelength (the waves get longer)
   C. Decrease in frequency (the waves become less frequent)
   D. Decrease in wavelength (the waves get shorter)

10. Imagine a fire truck with its siren blaring is moving towards an observer standing on a street corner. In this scenario, what would intensify the Doppler Effect?
    A. Have the observer move farther from the fire truck
    B. Increase the speed of the fire truck
    C. Decrease the speed of the fire truck

APPENDIX E: COMPREHENSION TEST SCORING RUBRIC*

Question 1 correct answer: B

Question 2 correct answer: A

Question 3 correct answer: B

Question 4 correct answers: A and D

Question 5 correct answers: B and C

Question 6 correct answer: A

Question 7 correct answer: C

Question 8 correct answer: A

Question 9 correct answer: B

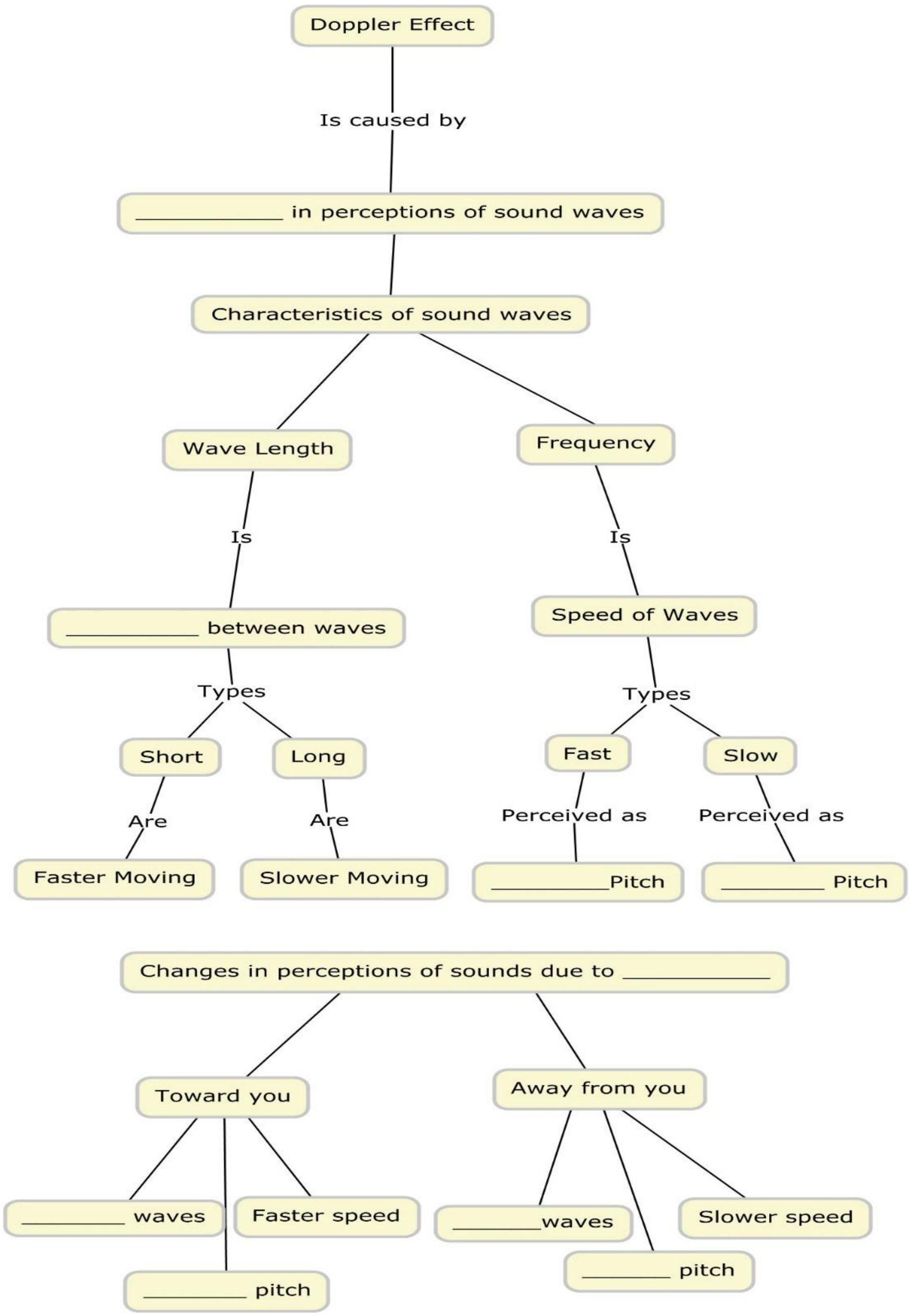
Question 10 correct answer: C

Scoring: 1 point per correct answer chosen and -1 point for every incorrect answer chosen

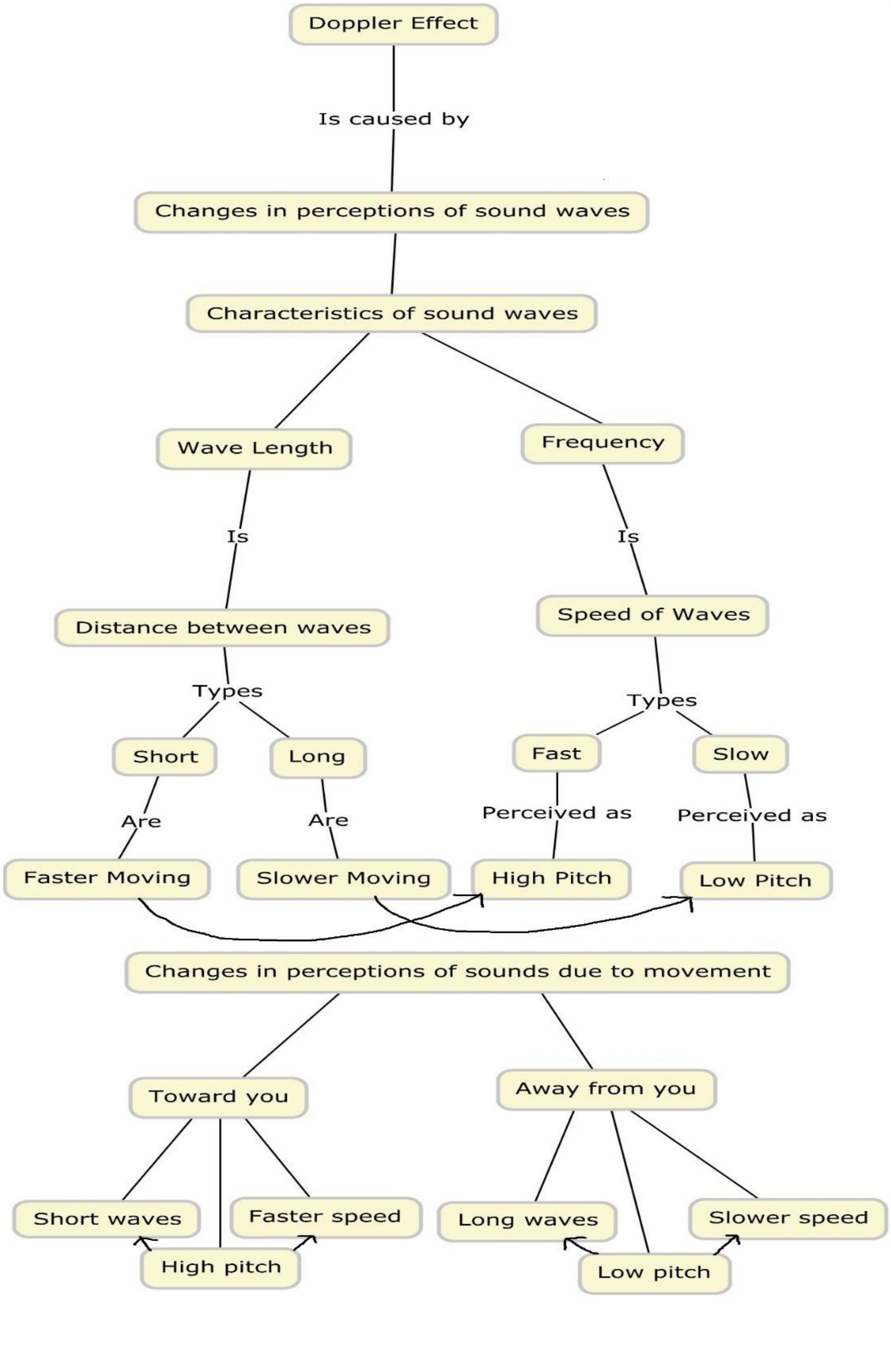
Number of possible points: 12

*For Test 1. The order of the questions and answer choices vary by test form, but the answers do not change.

APPENDIX F: INCOMPLETE CONCEPT MAP



APPENDIX G: COMPLETED CONCEPT MAP



APPENDIX H: CONCEPT MAP SCORING RUBRIC

1 point for each correct fill-in-the blank

0 points for each incorrect or empty blank

2 points for each correct cross-link drawn

0 points for each incorrect cross-link drawn

Number of possible points: 21

APPENDIX I: POST-EXPERIMENTAL SURVEY

Do you have previous experience with concept mapping? YES NO

How much experience with concept mapping have you had?

1 2 3 4 5

Extensive experience Much experience Moderate experience Little experience No experience

How often do you use concept mapping as a study technique for your classes?

1 2 3 4 5

Never Almost never Sometimes Very often Always

Do you have previous experience with the Doppler Effect? YES NO

How much experience with the Doppler Effect have you had?

1 2 3 4 5

Extensive experience Much experience Moderate experience Little experience No experience

How motivated were you to learn the material in this experiment?

1 2 3 4

Very motivated Motivated Neither motivated nor unmotivated Somewhat motivated

5

Not motivated

Please respond to the following questions using the scale below:

1 2 3 4 5

Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree

I was interested in the material on the Doppler effect.
I enjoyed this experiment.
I am likely to use concept mapping as a study technique in the future.
During the experiment, I felt that I understood the learning material on the Doppler effect.

I believe I did well on the comprehension tests.
I felt anxious during the experiment.

What is your age? ______

Circle your current class standing. Freshman Sophomore Junior Senior 5^{th} year Graduate Student Other

What is your major? ___________

Please indicate your current GPA. 3.5 – 4.0 3.0 – 3.5 2.5 – 3.0 2.0 – 2.5 Under 2.0

APPENDIX J: IRB APPROVAL

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Wednesday, October 11, 2017

Principal Investigator	**Lindsey Murry** (Student)
Faculty Advisor	Michael Hein
Co-Investigators	Sydney Cooper
Investigator Email(s)	*lm5g@mtmail.mtsu.edu; michael.hein@mtsu.edu*
Department	Psychology
Protocol Title	***Examining the mechanisms of the learning-by-teaching process through concept maps***
Protocol ID	**18-2054**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the categories *(7) Research on individual or group characteristics or behavior* (PRIMARY) and *(5) Research involving materials* (SECONDARY). A summary of the IRB actions and other particulars in regard to this protocol are tabulated below:

IRB Action	APPROVED for one year from the date of this notification
Date of expiration	**10/30/2018**
Participant Size	150 (ONE HUNDRED AND FIFTY)
Participant Pool	ADULT MTSU students (18 or older) - general population.
Exceptions	Permitted to collect identifiable infomration from the participants
Restrictions	1. **Mandatory signed informed consent.** **2. Identifiable information must be destroyed after data processing.** **3. Access to student records restricted to faculty advisor**
Comments	NONE

This protocol can be continued for up to THREE years (**10/31/2020**) by obtaining a continuation approval prior to **10/30/2018**. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	9/30/2018	TO BE COMPLETED
Second year report	9/30/2019	TO BE COMPLETED
Final report	9/30/2020	TO BE COMPLETED

Post-approval Protocol Amendments:

Date	**Amendment(s)**	**IRB Comments**
NONE	NONE	NONE

The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:

Click here for a detailed list of the post-approval responsibilities.
More information on expedited procedures can be found here.

APPENDIX K: CONCEPT MAPPING TRAINING SCRIPT

Hand out pictures of the two concept maps. What I am passing out are concept maps. Today, we are going to be learning how to create concept maps. Concept maps have been shown by many Educational and Cognitive Psychologists to be an effective learning technique, one that you may want to try for your own studies.

A concept map is an arrangement of nodes (circles, ovals, or rectangles) that represent key concepts and lines that connect the nodes describing the key relationships among concepts. Concept maps can also contain cross-links that that show relationships between concepts on different parts of the map. Concept maps are mostly hierarchical in structure, in that they should be read top-down, although some connections can be horizontal.

Practicing creating concept maps helps one to identify the important concepts of a topic, the causal relationships, and the connections between ideas. I have handed out a concept map about concept maps. Spend a few minutes looking at this concept map. Identify the concepts, connecting word and phrases, and cross-links. *Point out a couple of the main concepts and connections in the map.*

So, to construct a concept map, one first starts with a focus question, or main idea. There are then different steps one can take to complete a concept map. Some start by listing a set of concepts, while others will go directly to placing a main concept and start linking other concepts from it.

It is important to note that there are no "perfect" or "finished" concept maps; rather, they can always be revised to include more or less concepts or linkages, or connections and concepts may also be changed. What is important is that a concept map contains accurate information and makes sense to the author so it can be used as a learning tool.

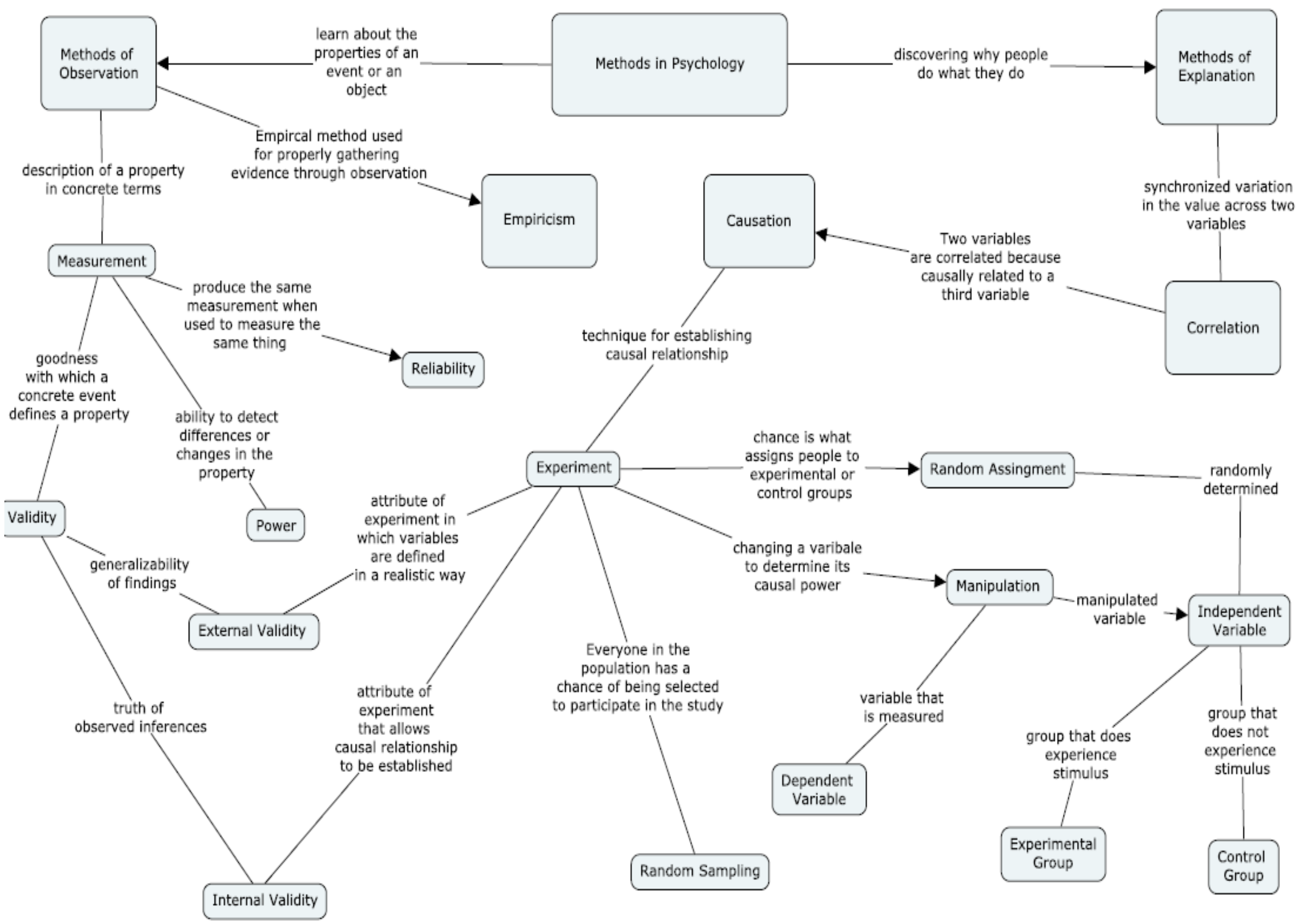
The second concept map I've handed out has the focus question: What are birds? Examine all of the concepts and relationships in this map.

We will now work on creating a concept map together. The focus question of this map is: What is a dog? Describe what you think about when you hear the word 'dog.' *Write the words and phrases students state on the board. Start linking some concepts and phrases together.* What else describes a dog? *Further differentiate into sub-concepts.* Notice the relationships between the concepts in the map. Are there any that are related to each other? Draw any necessary cross-links between concepts. What we have now is a simple concept map, although it is possible to continue to add ideas to it to make it more specific and detailed.

Now you will practice creating your own concept map. The focus question is: Methods in Psychology from chapter 2 in your textbook. First, think of the main ideas and write them down. Next, think about how some of these ideas are related to each other. This is the process of creating the linking phrases. Use arrows to connect the related ideas with a few words that describe the relationship. These linking phrases will often be verbs. Next, look at your map and identify any concepts that can be further divided into more specific sub-concepts. Finally, see if there are any concepts in your map that are not currently linked, but that are related. These can be "cross-linked," such as the relationship between "Creativity" and "Interrelationships" shown in the first concept map above.

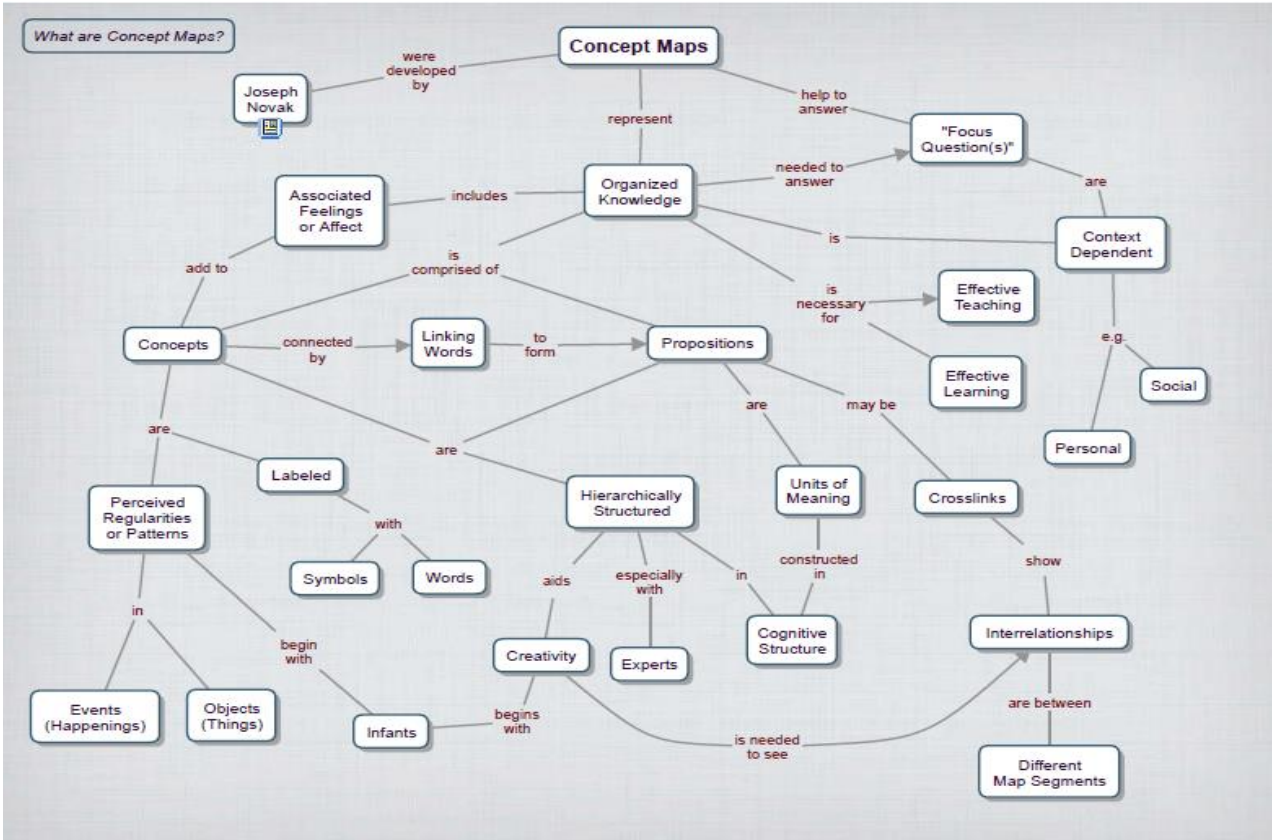
Can I get a couple of volunteers to come draw their maps on the board? *Once they are finished, read over the map out loud and point out the concepts and linkages. Describe the successful relationships they formed in the map as well as any improvements or additions that could be made.*

**Example map with these topics:*



Are there any final questions about concept mapping? I will be passing out a hand-out with some more information about concept mapping, as well as a link to an online concept mapping tool that you can practice with and use for your studies. *Hand out page with more information about concept mapping.*

APPENDIX L: CONCEPT MAPPING TRAINING HANDOUT



1

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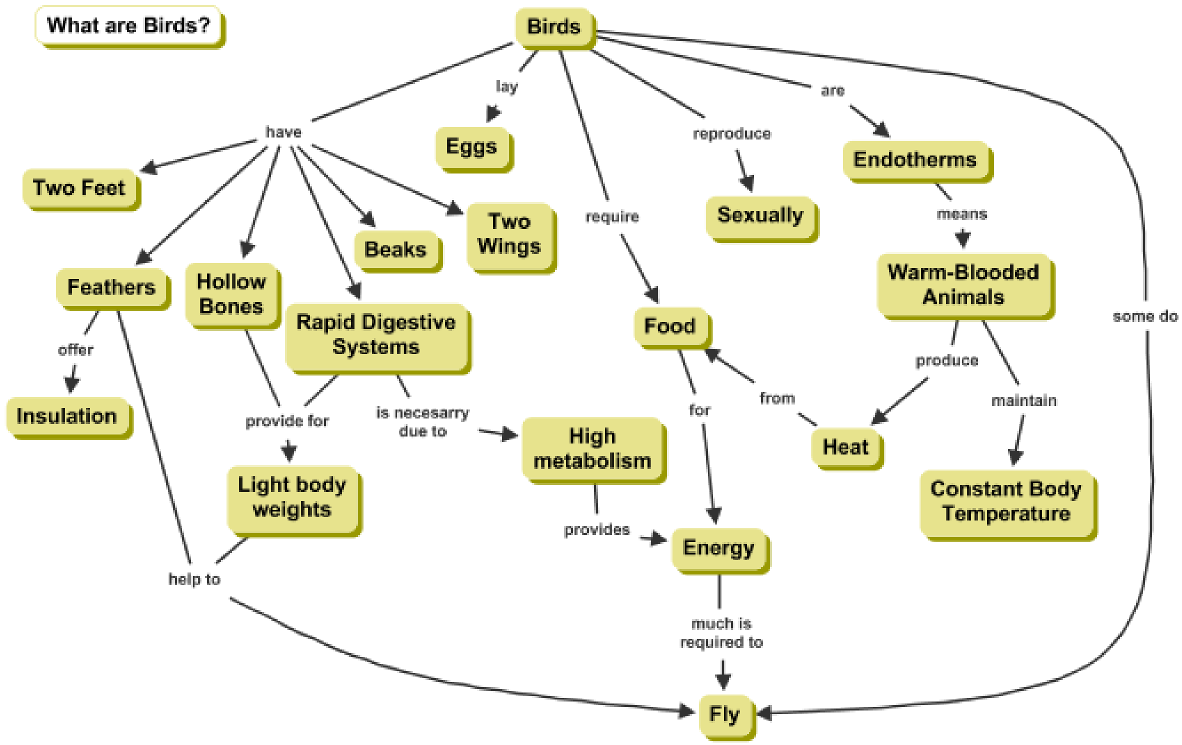
[1] Cañas, A. J., & Novak, J. D. Constructing Your First Concept Map. In *Cmap*. Retrieved from http://cmap.ihmc.us/docs/constructingaconceptmap.php.



[2]

[2] Cañas, A. J., & Novak, J. D. Constructing Your First Concept Map. In *Cmap*. Retrieved from http://cmap.ihmc.us/docs/constructingaconceptmap.php.

Concept Mapping

Steps to form a concept map: [3]

1. Identify a focus question that addresses the problem, issues, or knowledge domain you wish to map. Guided by this question, identify 10 to 20 concepts that are pertinent to the question and list these. Some people find it helpful to write the concept labels on separate cards or Post-it notes so that they can be moved around. If you work with computer software for mapping, produce a list of concepts on your computer. Concept labels should be a single word, or at most two or three words.
2. Rank order the concepts by placing the broadest and most inclusive idea at the top of the map. It is sometimes difficult to identify the broadest, most inclusive concept. It is helpful to reflect on your focus question to help decide the ranking of the concepts. Sometimes this process leads to modification of the focus question or writing a new focus question.
3. Work down the list and add more concepts as needed.
4. Begin to build your map by placing the most inclusive, most general concept(s) at the top. Usually there will be only one, two, or three most general concepts at the top of the map.
5. Next select the two, three, or four sub-concepts to place under each general concept. Avoid placing more than three or four concepts under any other concept. If there seem to be six or eight concepts that belong under a major concept or sub-concept, it is usually possible to identify some appropriate concept of intermediate inclusiveness, thus creating another level of hierarchy in your map.
6. Connect the concepts by lines. Label the lines with one or a few linking words. The linking words should define the relationship between the two concepts so that it reads as a valid statement or proposition. The connection creates meaning. When you hierarchically link together a large number of related ideas, you can see the structure of meaning for a given subject domain.
7. Rework the structure of your map, which may include adding, subtracting, or changing superordinate concepts. You may need to do this reworking several times, and in fact this process can go on indefinitely as you gain new knowledge or new insights. This is where Post-it notes are helpful, or better still, computer software for creating maps.
8. Look for crosslinks between concepts in different sections of the map and label these lines. Crosslinks can often help to see new, creative relationships in the knowledge domain.
9. Specific examples of concepts can be attached to the concept labels (e.g., golden retriever is a specific example of a dog breed).

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[3] Novak, J. D. (1998). *Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations* (pp. 227-228). Mahwah, NJ: Lawrence Erlbaum Associates.

10. Concept maps could be made in many different forms for the same set of concepts. There is no one way to draw a concept map. As your understanding of relationships between concepts changes, so will your maps.

Free online concept mapping software:

Cmap © IHMC: https://cmap.ihmc.us/

For more information about concept mapping:

Fiorella, L., & Mayer, R. E. (2015). Learning as a generative activity: Eight learning strategies that promote understanding. New York: Cambridge University Press, 2015.

Novak, J. D., & Cañas, A. J. (2008). The theory underlying concept maps and how to construct and use them. Retrieved from http://cmap.ihmc.us/docs/theory-of-concept-maps.php

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Cambridge University Press.

Salmon, D., & Kelly, M. (2015). *Using Concept Mapping to Foster Adaptive Expertise: Enhancing Teacher Metacognitive Learning to Improve Student Academic Performance*. New York, NY: Peter Lang.

Many additional documents available at: https://cmap.ihmc.us/docs/learn.php

APPENDIX M: EXPERIMENTAL INSTRUCTIONS

1. Condition 1 instructions

Now you will begin the experiment. I will shortly be passing out a text that explains a popular physics concept, the Doppler effect. You will have 25 minutes to read and study this text. Feel free to take notes on the lesson itself or on the blank sheet of paper you will be given with the lesson. Please use the entire 25 minutes to read, study, and take notes on the material. After reading, you will answer questions about the Doppler effect. You will not be able to use your notes while answering the questions. Are there any questions before we begin?

2. Condition 2 instructions

Now you will begin the experiment. I will shortly be passing out a text that explains a popular physics concept, the Doppler effect. You will have 20 minutes to read and study this text, and will then be asked to teach the material that you have learned. Feel free to take notes on the lesson itself or on the blank sheet of paper you will be given with the lesson. Please use the entire 20 minutes to read, study, and take notes on the material. Next, you will be instructed to follow the researcher to the room in which you will record a lesson on a camcorder that teaches the material in the text, for someone else to learn the material from. You have up to 5 minutes to record your lesson. When you are finished, let the researcher who will be in the hall know. Are there any questions before we begin?

3. Condition 3 instructions

Now you will begin the experiment. I will shortly be passing out a text that explains a popular physics concept, the Doppler effect. You will have 15 minutes to read and study this text. Feel free to take notes on the lesson itself or on the blank sheet of paper you will be given with the lesson. Please use the entire 15 minutes to read, study, and take notes on the material. After reading, you will answer questions about the Doppler effect. You will not be able to use your notes while answering the questions. You will then be given an incomplete concept map, with the number of concepts and connections specified. You will have 10 minutes to finish filling in the blanks on the map and to add any additional information to the map. Are there any questions before we begin?

4. Condition 4 instructions

Now you will begin the experiment. I will shortly be passing out a text that explains a popular physics concept, the Doppler effect. You will have 10 minutes to read and study this text and will then be asked to teach the material that you have learned. Feel free to take notes on the lesson itself or on the blank sheet of paper you will be given with the lesson. Please use the entire 10 minutes to read, study, and take notes on the material. Next, you will be instructed to follow the researcher to the room in which you will record a lesson on an iPad that teaches the material in the text, for someone else to learn the material from. You have up to 5 minutes to record your lesson. When you are finished, let the researcher who will be in the hall know. You will then return to the original room and will be given an incomplete concept map, with the number of concepts and connections specified. You will have 10 minutes to finish filling in the blanks on the map and to add any additional information to the map. Are there any questions before we begin?