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Technology-supported collaborative concept maps in classrooms

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Abstract

This article explores how the use of concept mapping, with and without technology support, assists students in learning complex concepts to which they may have had limited previous exposure. Students were engaged in a group-based concept mapping activity, wherein they created two concept maps over the course of several weeks in a large lecture class. A quasi-experimental design was used in which students were randomly assigned to groups of three, and groups were randomly assigned to concept mapping condition: (a) using pencil/paper followed by using an iPad application or (b) using an iPad app followed by using pencil/paper. Concept maps were scored for complexity (correctness and elaborateness), and scores were compared within group and between groups across conditions (pencil/paper vs. iPad app). Results showed that concept maps did not differ in quality between conditions or across time. Moreover, there was no significant difference between examination scores of the students. Finally, content analysis was conducted on students' written evaluations of the pros and cons of concept mapping using pencil/paper and using the iPad app. Student evaluations indicated both pros and cons for each concept mapping condition.

Keywords

BaiBoard, collaborative learning, college classrooms, concept maps, iPad

What is concept mapping?

A number of different educational tools are being used in classrooms in order to promote students' understanding and deeper learning, especially by illustrating and embodying abstract topics. One of these tools is concept mapping. Concept mapping has been demonstrated to promote learning of complex material in learners of a variety of ages in a variety of different learning situations (Nesbit and Adesope, 2006). Concept mapping can be particularly effective when maps are created in a group setting (Haugwitz et al., 2010; Kwon and Cifuentes, 2009). As digital devices such as tablet

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computers become increasingly common in the college classroom, instructors have opportunities to experiment with established instructional approaches in light of the novel affordances of those devices. Concept maps are defined as "graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts" (Novak and Cañas, 2006: 1), and as two-dimensional, hierarchical, node-link diagrams that represent verbal, conceptual, or declarative knowledge in visual or graphic forms (Quinn et al., 2003). The concept map that is developed by the learners about a specific topic is then a working framework of their current cognitive structure (Daley, 2010). In a well-designed concept map, concepts are presented in hierarchical order from most general to most relevant one that the relationships between the concepts are shown via cross-links. Furthermore, the best way of constructing a concept map is directing particular questions to learners in order to let them focus the topic and seek answers (Novak and Cañas, 2006).

Even though research has demonstrated the benefits of using concept mapping in non-educational organizations, the majority of research has focused on using concept maps in educational settings in order to support meaningful learning (Blunt and Karpicke, 2014; Novak and Gowin, 1984; Redford et al., 2012). When learners asked to prepare a concept map, especially on a non-familiar topic, they are forced to link former and current concepts in a meaningful way which let them to think out of the box that brings out novel ideas. This process of mapping connections facilitates the use of higher order thinking skills (Bloom, 1956; Buldu and Buldu, 2010; Karpicke, 2012; Karpicke and Blunt, 2011), and supports content learning by illustrating the state of the learners' current understanding, facilitating awareness of knowledge gaps and misconceptions (Chiou, 2008; Novak, Gowin and Johansen, 1983), and assisting learners in understanding their own learning process (Buldu and Buldu, 2010; Blunt and Karpicke, 2014; Horton et al., 1993; Karpicke, 2012; Karpicke and Blunt, 2011; Novak et al., 1983; Novak and Gowin, 1984; Novak and Musonda, 1991).

More specifically, research has identified the benefits of concept mapping as a follow-up strategy in text learning (Hilbert and Renkl, 2008). Creating a concept map after text learning forces students to relate new information to previous knowledge; this process requires students to determine which ideas are important and how they are interrelated, fostering an elaboration process (Weinstein and Mayer, 1986). The creation of the map itself, putting certain groups of concepts together and connecting them through meaningful paths to other concepts, helps the learner to create a coherent structure of knowledge. Finally, post text-learning concept mapping facilitates metacognitive processes by making comprehension gaps clear. Students become aware of where their understanding of the material is incomplete. The ability of concept mapping to promote metacognitive awareness has been shown to be especially important for those who are poor readers (Liu et al., 2010). Not only does concept mapping encourage productive concept synthesizing and metacognition, but research has also provided evidence that concept mapping can improve learning compared to other learning forms. A meta-analysis showed that having students create open-ended concept maps resulted in significantly greater learning gains as compared to other control methods (Nesbit and Adesope, 2006). New research has begun to discuss the benefit of combining the educational benefits of concept mapping with the benefits of collaborative learning.

Collaborative learning and concept mapping

Traditional teaching methods have been associated with passiveness that students mostly memorize the information instead of conceptual understanding (Majerich et al., 2011). Although all instructors demand that their students actively participate in the course, they commonly complain about the passiveness of students. A vital element of active participation is involvement that students will participate in class, work hard, and try to achieve the goals, and that they will do so as long as they feel involved. If not, they take a more passive role and do not try hard (Bojinova and Oigara, 2011; Hunsinger et al., 2008; Mayer et al., 2009). So, many educational institutions and instructors seek a solution to passiveness in students, and try different educational approaches and methods in order to support active participation and engage them (Herrmann, 2013).

Collaborative learning is one of the widely used instructional methods which supports active learning in a class medium (Abuseileek, 2012; Yang and Liu, 2005) due to its several advantages in all levels of education (Herrmann, 2013; Yang and Liu, 2005). In collaborative learning, students with various performance levels work together in small groups in order to achieve common goals via within-group and between-groups discussions, and by using peer feedback (Foldnes, 2016; Gokhale, 1995). Collaborative learning stresses the importance of working as a group, which might allow them to share their insights and worldviews, and to constitute a shared purpose that might boost motivation and promotes critical thinking (Cavanagh, 2011; Davis, 2009; Gokhale, 1995; Johnson and Johnson, 1986; Kirschner et al., 2011; Totten et al., 1991). Within-group and between-groups discussions in collaborative learning allow students to understand the concepts on account of building their own knowledge while seeking for a solution and defending their position (Kapitanoff, 2009). Collaborative learning requires students to perceive other students' understanding and incorporate with their own understanding a technique that lends itself nicely to the demands of concept mapping.

Concept mapping is a helpful technique being used for both individual and collaborative learning. For example, students might represent their ideas and concepts socially for a group study which allows them to construct their own, internalized complex cognitive structures (Stoyanova and Kommers, 2002). Multiple groups might profit from working on a specific concept map together via joint brainstorming concepts and discussing relations among the concepts (Cicognani, 2000). Furthermore, different groups might offer modifications to create a more comprehensive and thorough map during the mapping (Cicognani, 2000). What matters the most in the creation of the concept maps leading to meaningful learning is whether the students successfully include links with labels between concepts (Hilbert and Renkl, 2008). They also noted that although learners were able to recognize their incomplete knowledge of the material, they were not always able to overcome it. This may be where concept mapping in a collaborative setting may be more beneficial than individual mapping, as a peer may be able to fill in the gaps where a student would otherwise become stuck (Cicognani, 2000).

Research reported that collaborative concept maps were more elaborate than those that were conducted individually, demonstrating the benefits of collaborative mapping (Kwon and Cifuentes, 2009). Students who were assigned to create collaborative concept maps rather than a conventional collaborative written summary obtained higher scores on a post-test (Haugwitz et al., 2010). Brown (2003) investigated collaborative concept mapping compared to individual concept mapping and other study strategies. They found that the students who engaged in group mapping outperformed those who conducted individual mapping or who did not use concept maps at all. These studies affirm that working collaboratively helps students fill gaps in their individual knowledge by receiving input from other students. These benefits make concept mapping an apt technique to be used with collaborative learning and now with the introduction of digital devices into education settings, concept maps have taken on different media.

Mapping with iPads

Even though practice, feedback, and active participation are known as three key elements of learning in a class, the structure of traditional classrooms and large number of enrolled students constitute barriers and obstruct learning (Patterson et al., 2010; Trees and Jackson, 2007; Wolter et al., 2011). However, in a traditional classroom, particularly where class sizes are large, a limited number of students have a chance to interact with the instructor or other students (Bojinova and Oigara, 2011), although the use of new technologies may assist in this (Wood, 2004).

Educational institutions, especially universities, are required to keep up with current technology (Campbell, 2015) in a world where all students were born and have grown up in a technology-rich era (Gu et al., 2013; Margaryan et al., 2011). The duty of these institutions is not only to provide the technology but also to teach students what to use, how to use it, and the rationale for using it (Campbell, 2015). There has been a shift from traditional classrooms to technology-enhanced learning environments (Geng, 2013). Furthermore, mobile learning and mobile devices offer a convenient, efficient, and affordable information technology learning environment (Geng, 2013). Moreover, the increasing interest in using mobile technology and social networking tools by students allows educational institutions to seek new ways to use social media and mobile learning in education (Demirbilek, 2015; Gikas and Grant, 2013). One of the mobile devices gaining popularity is tablet computers. Many students already own or are willing to own one while studying at university (Jones et al., 2010; Margaryan et al., 2011). According to Mobile Fact Sheet (2017), 77% of American adults have smartphones and 51% have tablet computers. The iPad is one of the touch screen tablet computers released in 2010 by Apple, and it has been adopted all around the world (Nguyen et al., 2015). According to Gordon (2017), more than 350 million iPads have been sold since its release. Introducing iPad to educational institutions was a natural step to support active learning in a class medium due to its potential (Hargis et al., 2014), since many institutions have started to seek ways of using iPads for teaching and learning (Nguyen et al., 2015). Supporting interaction and collaboration are two main advantages of tablet.

As tablet devices have become increasingly common in the college classroom, instructors are able to experiment with established instructional tools and techniques such as concept mapping and collaborative learning in light of the novel affordances of these. When the literature is examined, it is seen that there are a number of studies conducted to examine concept mapping activities. However, the number of technology-supported concept mapping activities, especially mapping with tablet computers, is limited, and most of the studies conducted have been with younger students. Furthermore, while the advantages of collaborative learning have long been known and this has been used, empirical evidence of using collaborative learning in higher education is limited (Herrmann, 2013). There is a need to investigate the use of technology-supported, collaborative concept maps in classrooms. In this context, the use of iPads to create concept maps, its effects on complexity of concept maps and collaboration among students, and thoughts of students on mapping with iPad vs traditional method need to be investigated. That is, to investigate whether allowing students in small collaborative learning groups to create concept maps using an iPad application as compared to pencil/paper would affect the nature of the concept maps, the extent of students' individual learning, or their satisfaction with the concept mapping process.

Method

Participants

A convenience sampling method was employed. Participants of the study were 92 second- and third-year students enrolled in a developmental psychology course offered by the researcher for education majors at a large university in the southwestern United States. The participants were 78% female and 22% male, ranged in age from 18 to 22 years. A large majority of participants were Caucasian, reflecting the demographic of the college overall.

Data collection process

The research was conducted as part of 5-year one-to-one initiative. The university had started a technology initiative in summer 2012, and College of Education was chosen as the pilot group of the initiative. Each faculty and student of the College of Education was given an iPad as part of the initiative. Faculty members were asked to implement these devices into their courses and classes, and the students were asked to use them with or without educational purposes as much as possible. The data were collected in collaboration with a faculty member who implemented iPad into her classes, and aimed at investigating how the use of tablets can enhance the collaborative process of creating a concept map as part of one-to-one technology initiative. The faculty member had been using concept maps as part of her classes for years in order to reveal the misconceptions of students to support self-learning.

Concept maps

Over the course of the study, students working in small groups prepared three different concept maps, as described below. Approximately 1 week elapsed between each concept mapping session. All three concept maps were graded as a regular component of the students' course.

A quasi-experimental design was used in which students were randomly assigned to one of 30 small groups at the beginning of the study. Two of the groups had four members each; all other groups had three members each. Groups remained stable during the course of the study. Each group was asked to prepare three different concept maps on different topics during the study. Furthermore, they were asked to finish each concept map during class time, so groups collaborated face to face while also jointly creating their concept maps.

At the training trial, students were introduced to concept mapping as an instructional strategy, and were also introduced to the iPad application BaiBoard HD. BaiBoard HD, published by LightPlaces Ltd, is described as "a free online meeting playground service that enables real-time collaborative drawing with its feature-rich drawing tools and collaborative services." The instructional advantages of using BaiBoard HD for collaborative concept mapping were expected to be twofold: First, the flexibility afforded by BaiBoard HD to easily add, delete, label, and rearrange both the concepts and the connectors in the map was expected to enhance group discussion of those relationships. That is, being freed from the labor of erasing and redrawing concepts and connectors during the map drafting process (as they would need to do with pencil/paper), students could more deeply discuss and more accurately illustrate the relationships among the concepts. Second, the fact that all users could see and directly manipulate the evolving map on their own tablet at all times was expected to lead to higher quality engagement of all group members, as compared to the pencil/paper condition wherein only a single person can directly manipulate the concept map at any given time.

Students were instructed to use BaiBoard HD to create a concept map illustrating relationships among 15 assigned concepts concerning families and child development. Creation of this concept map allowed students to become familiar with the process of concept mapping and with the affordances of the BaiBoard HD application. As this was a training trial, these concept maps were not analyzed for correctness or elaborateness.

For the first concept map, students were asked to create a concept map to illustrate the relationships among 21 concepts from Piaget's theory of cognitive development. During this implementation, half of the students (groups 1–15) were instructed to create the concept map on paper. The rest of the students (groups 16–30) were instructed to create the concept map on their iPads using BaiBoard HD.

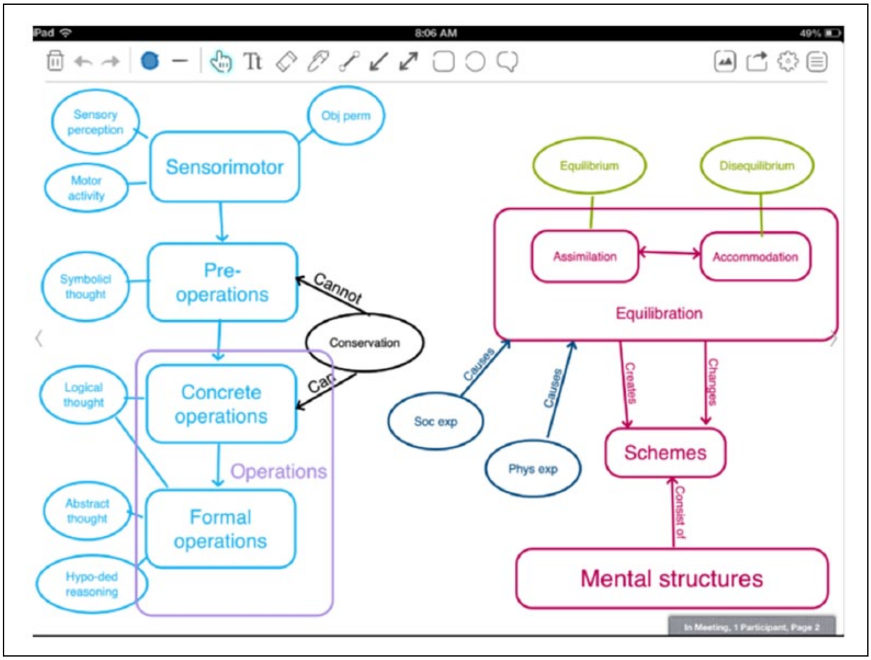

Figure 1. An example of a concept map created with BaiBoard HD.

For the second concept map, students were asked to create a concept map to illustrate the relationships among 14 concepts from Vygotsky's theory of cognitive development. During this implementation, assignment to the paper versus tablet condition was reversed. That is, students in groups 16–30 created their maps on paper, while groups 1–15 created their maps on their iPads using BaiBoard HD. An example of a concept map created with BaiBoard HD can be found in Figure 1. An example of a concept map created on paper can be found in Figure 2.

Examination scores: As an element of course completion, students take an examination at the end of each unit. As part of this study, students took an examination consisting of 22 multiple-choice questions that covered the topics taught using the concept mapping. Eleven were related to Piaget's theory, the first concept map topic, and 11 related to Vygotsky's theory, the second concept map topic. All questions were prepared by the faculty member who has been offering the course more than 10 years. Although each student was given an individual examination, a group score was calculated at the end by adding individual scores and dividing into number of group members in order to compare with mapping scores.

Student evaluation of concept mapping under each condition: After completing the concept mapping process, each student was requested to respond individually in writing to a set of prompts regarding the pros and cons of concept mapping on paper and on iPads. Furthermore, additional observation notes were taken, and responses given by the students were noted during class time and collected upon completion.

Data analysis

Three different scoring and analysis procedures were employed. At first, concept maps were scored for *Correctness* (0–5 possible points) and *Elaborateness* (0–5 possible points). Correctness was

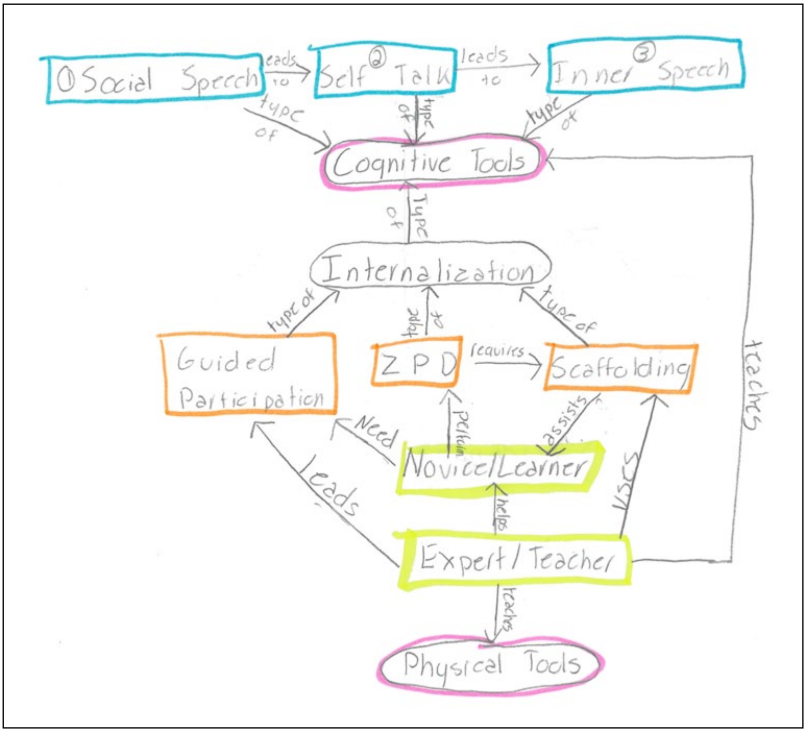

Figure 2. An example of a concept map created on paper.

determined by comparing student-generated maps to a map created by an expert, the course instructor, as suggested by Novak et al. (1983). Maps that received higher points on correctness correctly represented the five specific relationships that were determined to be imperative by the researchers. Each point was awarded for a correct representation of concepts. Elaborateness was scored on the extent to which a map illustrated groupings of concepts (e.g. as signaled by use of differing shapes, colors, or fonts) and relationships among concepts or groups of concepts (e.g. as signaled by the use of lines, arrows, double-headed arrows, and nesting; and by labeling connectors), and on overall organization. A rubric was created using the master map to guide raters in their delineation of points for each concept map. Any confusion or uncertainty of point distribution was marked.

Each map was independently scored by two different raters, each of whom was a doctoral student in educational psychology/instructional technology. Following a training phase, raters independently scored five maps, and then compared scores to determine interrater reliability. Having established a high degree of reliability (an 88% one-to-one agreement between raters), raters continued to score the full set of concept maps. After all maps were scored, the two raters met to compare scores. Discrepancies in scoring were resolved through discussion.

Concept map scores were used in two different statistical analyses. Concept map scores (correctness and elaborateness) were compared across conditions to determine whether the data suggested a practice effect for concept mapping and concept map scores across conditions. Secondly, exam sub-scores on Piaget's theory and examination sub-scores on Vygotsky's theory were compared across conditions. Lastly, content analysis was conducted on students' individual reflective assignments to reveal patterns in their thoughts about paper versus iPad as a concept-mapping platform.

During the data analysis process, paired sample *t*-test and independent sample *t*-test were employed. While paired sample *t*-test is used "when there are two experimental conditions and the same participants took part in both conditions of the experiment" (Field, 2009: 325), independent sample *t*-test is used "when there are two experimental conditions and different participants were assigned to each condition" (325). In the study, paired sample *t*-test was employed in order to reveal whether there was a significant difference between the first and second concept map elaborateness and correctness scores within each group. Besides, independent sample *t*-test was employed in order to reveal whether there was a significant difference between elaborateness and correctness scores of conditions; in other words, between groups assigned to paper or iPad treatment. Moreover, additional independent sample *t*-test was employed in order to compare examination scores of the groups assigned to paper or iPad treatment. In addition to quantitative analysis, a small-scale qualitative analysis was conducted on students' reflection papers. All students were required to submit a reflection paper in order to determine the pros and cons of concept mapping with paper/pencil and iPad. After collecting all submitted reflection papers, the researcher and the second-coder content analyzed and created codes.

Results

There was no significant difference between elaborateness scores for map 1 ($m=4.42$, SD=0.65) and elaborateness scores for map 2 ($m=4.71$, SD=0.46; $t(23)=0.09$, $p>0.05$) for paired groups. Furthermore, there is no significant difference between correctness scores for concept map 1 ($m=3.43$, SD=0.73) and correctness scores for concept map 2 ($m=3.22$, SD=1.04; $t(22)=0.41$, $p>0.05$).

There was no significant difference between elaborateness scores of paper/pencil concept maps ($m=4.67$, SD=0.56) and elaborateness scores of iPad using BaiBoard HD concept maps ($m=4.46$, SD=0.59; $t(23)=0.23$, $p>0.05$). Furthermore, there was no significant difference between correctness scores of paper/pencil concept maps ($m=3.52$, SD=0.79) and correctness scores of iPad using BaiBoard HD concept maps ($m=3.13$, SD=0.97; $t(22)=0.13$, $p>0.05$).

There was no significant difference between Piaget's examination item scores of paper/pencil concept maps ($m=0.74$, SD=0.19) and Piaget's examination item scores of iPad using BaiBoard HD concept maps ($m=0.73$ SD=0.07; $t(23)=0.95$, $p>0.05$). Furthermore, there was no significant difference between Vygotsky's examination item scores of paper/pencil concept maps ($m=0.72$, SD=0.09) and Vygotsky's examination item scores of iPad using BaiBoard HD concept maps ($m=0.71$ SD=0.15; $t(23)=0.77$, $p>0.05$).

With regard to students' individual thoughts about paper versus iPad as a concept-mapping platform, both media were considered to have several advantages and disadvantages (Table 1).

The major advantages that emerged for mapping with iPad using BaiBoard HD were creating more organized concept maps ($n=18$), supporting collaboration ($n=17$), and ease of reorganizing concept maps ($n=15$). The major disadvantages were considered to be technology issues such as the freezing of the app, the small workplace ($n=22$), and unfamiliarity with the technology ($n=19$). While being easy to use ($n=19$) and being what they have been using (n=12) were considered to be the major advantages of using paper/pencil, being unorganized compared to iPad using BaiBoard HD version ($n=18$), and being unable to reorganize ($n=10$) were considered to be the major disadvantages.

Discussion and conclusion

Studies show that using concept maps has positive effects on students learning (Chiou, 2008; Hwang et al., 2013; Novak et al., 1983; Novak and Gowin, 1984). The results of the study described

Table 1. Students' comments about using BaiBoard HD and paper/pencil.

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Advantages that emerged for mapping with iPad	
Looked more organized/nicer	18
Good for collaboration	17
Don't have to start over if you mess up/easy to erase	15
Could type concepts before committing to where to put them	8
Convenient	7
Helped become more familiar with technology	5
Not just one person doing all the work	1
Disadvantages that emerged for mapping with iPad	
Technology issues (App freezing up, turning in the map, small work space)	22
Difficult becoming familiar with the technology	19
Time consuming	9
One person did all the work	2
Advantages that emerged for mapping with pencil/paper	
Simpler/easier to use	19
What I'm used to	12
Faster	8
Focus more on content instead of the task of mapping itself	7
Allows for creativity	7
Easier to make a rough draft	5
Disadvantages that emerged for mapping with pencil/paper	
Not as organized/neat/pretty as iPad version	18
If you make a mistake you have to start over/hard to erase	10
Multiple drafts	5
Less efficient	3
Time consuming	2
One person does all the work	1

in this article suggest that the platform used for creating the concept maps (paper/pencil vs. iPad using BaiBoard HD) does not affect the complexity of the concept maps or performance on related examination items. Although technological devices were not produced for educational use, many of them were adapted to educational system and admitted as a revolutionary solution to educational problems. Nevertheless, none of these devices were reached to high goals as expected. For instance, in 1913, Edison stated that motion picture would solve the educational problems, books would be useless, and all the information that humankind had would be told via motion picture (Cuban et al., 2001; Reiser and Dempsey, 2002), but it was not. What is more, just providing equipment and software does not lead to efficient and effective use, and support learning (Cuban et al., 2001). As Clark (1983, 1994) claimed, the same subject could be taught and that the same goals could be reached via several different media, that is, that the media chosen would have no unique effect. The chosen media might ease or fasten the process, but it might be more effective when used along with proper method.

One issue noticed during classroom observation is that some groups were quite resistant to mapping using their assigned condition. Although the current generation was born in a technology era and considered to be technology-competent individuals, it was seen that they were not fully switched to a digital medium. Some students still preferred to work on traditional paper-and-pencil medium. That is, a few groups in the BaiBoard condition were found preparing ‘rough drafts’ of their concept map using paper/pencil with plans to ‘copy’ the final draft into BaiBoard HD. Likewise, one group in the paper/pencil condition was found creating a map on BaiBoard with the intention of then drawing the completed map on paper to turn in. This propensity was borne out in individual student comments that indicated preferences for one condition over the other. These non-compliant groups were quickly identified and directed to use only the assigned method for creating their concept map. Therefore, the influence on our data is likely to be minimal, but this does point out the role of student attitudes toward technology on these types of studies.

Group working strategies such as collaborative learning, cooperative learning, and problem-based learning might help students interact more and to feel engaged. Even though the result of the study showed that there was no significant difference between concept-mapping scores and examination scores of traditional paper-and-pencil medium and technology-supported one, technology might ease the way of collaboration and interaction, despite concerns about using digital technology for teaching and learning (Henderson et al., 2016). This was a small-scale study, so more comprehensive experimental studies, that is, using pretest–posttest design or Solomon four group design, might better serve to understand the effect of using technology for teaching and learning.

As with all studies, this study had some limitations: The main limitation of the study was the sample size. The data were collected from 92 second-year College of Education students. Even though the class size was big, it decreased to 30 when the groups were created. Furthermore, some groups were withdrawn from the study as they were not able to attend all sessions, and the number of groups decreased during the data collection process. Having more students or collecting data from a bigger sample might have resulted in statistically different results. Furthermore when groups were created, any role was defined to group members. They were asked to work and collaborate with other members of the group. A faculty member and two TAs were in the classroom, and walked around each group in order to ensure that participation and seemingly equal work were being done within the groups. Even though three instructors were around, the results might have been different had each member of each group been assigned a specific role. Another limitation is the demographics of the students, in that all participants were second-year College of Education students from different disciplines, and 78% of the participants were female. Although having participants from different majors might be thought as an advantage for generalizability, students from different majors may have different skills and levels of technology use that might impact the data collected. Having just sophomores as participants and being mostly women limit the generalizability. Moreover, the duration of the study was a limitation. Three sessions, one of which was introduction, were held with students as a supplementary part of the course. This 3-week long application might be too short to determine the pros and cons of technology-supported teaching and learning that longitudinal studies might reveal.

Another limitation of the study was the app used. There was no other app that allowed students to create a synchronous concept map on different devices during the data collection. Using different apps might allow students to benefit more from the technology. The complexity (correctness and elaborateness) of concept maps might be higher when maps are created on iPad using BaiBoard HD. It is possible that differences in map quality between groups might be expected to be higher if students were more comfortable with the concept-mapping application. BaiBoard HD was a new app for the students, and they may have needed more time to become fully familiar and comfortable with its use. This was borne out by student comments about the disadvantages of using the app. Theoretically, one would expect that the use of the app would lead to a richer discussion of the relationships among concepts within the groups and, ultimately, better understanding of those concepts for two reasons: First, the flexibility afforded by BaiBoard HD to easily add, delete, label, and rearrange concepts and connectors in the map. Second, the fact that all users could see and manipulate the evolving map on their own tablet screens at all times. Future work is needed to determine whether these benefits would become more apparent with greater familiarity with the app, or if the platform really does not affect concept map quality.

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References

Abuseileek AF (2012) The effect of computer-assisted cooperative learning methods and group size on the EFL learners' achievement in communication skills. *Computers & Education* 58(1): 231–39.

Bloom BS, Engelhart MD, Furst EJ, et al. (1956) *Taxonomy of Educational Objectives: Handbook I: Cognitive Domain*. New York: David J. C. McKay.

Blunt JR and Karpicke JD (2014) Learning with retrieval-based concept mapping. *Journal of Educational Psychology* 106(3): 849–58.

Bojinova ED and Oigara, JN (2011) Teaching and learning with clickers: Are clickers good for students? *Interdisciplinary Journal of E-Learning & Learning Objects* 7:169–184.

Brown DS (2003) High school biology: A group approach to concept mapping. *The American Biology Teacher* 65(3): 192–97.

Buldu M and Buldu N (2010) Concept mapping as a formative assessment in college classrooms: Measuring usefulness and student satisfaction. *Procedia: Social and Behavioral Sciences* 2(2): 2099–104.

Campbell C (2015) Introducing a learner response system to pre-service education students: Increasing student engagement. *Active Learning in Higher Education* 16(1): 25–36.

Cavanagh M (2011) Students' experiences of active engagement through cooperative learning activities in lectures. *Active Learning in Higher Education* 12(1): 23–33.

Chiou C-C (2008) The effect of concept mapping on students' learning achievements and interests. *Innovations in Education and Teaching International* 45(4): 375–87.

Cicognani A (2000) Concept mapping as a collaborative tool for enhanced online learning. *Educational Technology & Society* 3(3): 150–58.

Clark RE (1983) Reconsidering research on learning from media. *Review of Educational Research* 53(4): 445–459.

Clark RE (1994) Media and method. *Educational Technology Research and Development* 42(3): 7–10.

Clark RE (1994) Media will never influence learning. *Educational Technology Research and Development* 42(2): 21–9.

Cuban L, Kirkpatrick H and Peck C (2001) High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal* 38(4): 813–34.

Daley BJ, Conceição SC, Mina L, et al. (2010) Concept mapping: A strategy to support the development of practice, research, and theory within human resource development. *Human Resource Development Review* 9(4): 357–84.

Davis BG (2009) *Tools for Teaching*, 2nd edn. San Francisco, CA: Jossey-Bass.

Demirbilek M (2015) Social media and peer feedback: What do students really think about using Wiki and Facebook as platforms for peer feedback? *Active Learning in Higher Education* 16(3): 1–14.

Field AP (2009) *Discovering Statistics Using SPSS: (and Sex and Drugs and Rock 'N' Roll)*, 3rd edn. London: SAGE.

Foldnes N (2016) The flipped classroom and cooperative learning: Evidence from a randomised experiment. *Active Learning in Higher Education* 17(1): 39–49.

Geng G (2013) Investigating the use of text messages in mobile learning. *Active Learning in Higher Education* 14(1): 77–87.

Gikas J and Grant MM (2013) Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media. *The Internet and Higher Education* 19: 18–26.

Gokhale AA (1995) Collaborative learning enhances critical thinking. *Journal of Technology Education* 7(1): 22–30.

Gordon K (n.d.). *Topic: iPad*. Available at: https://www.statista.com/topics/877/ipad/ (accessed 19 July 2017).

Gu X, Zhu Y and Guo X (2013) Meeting the "digital natives": Understanding the acceptance of technology in classrooms. *Educational Technology & Society* 16(1): 392–402.

Hargis J, Cavanaugh C, Kamali T, et al. (2014) A federal higher education iPad mobile learning initiative: Triangulation of data to determine early effectiveness. *Innovative Higher Education* 39(1): 45–57.

Haugwitz M, Nesbit JC and Sandmann A (2010) Cognitive ability and the instructional efficacy of collaborative concept mapping. *Learning and Individual Differences* 20(5): 536–43.

Henderson M, Finger G and Selwyn N (2016) What's used and what's useful? Exploring digital technology use(s) among taught postgraduate students. *Active Learning in Higher Education* 17(3): 1–13.

Herrmann KJ (2013) The impact of cooperative learning on student engagement: Results from an intervention. *Active Learning in Higher Education* 14(3): 175–87.

Hilbert TS and Renkl A (2008) Concept mapping as a follow-up strategy to learning from texts: What characterizes good and poor mappers? *Instructional Science* 36(1): 53–73.

Horton PB, McConney AA, Gallo M, et al. (1993) An investigation of the effectiveness of concept mapping as an instructional tool. *Science Education* 77(1): 95–111.

Hunsinger M, Poirier CR and Feldman RS (2008) The roles of personality and class size in student attitudes toward individual response technology. *Computers in Human Behavior* 24(6): 2792–98.

Hwang GJ, Yang LH and Wang SY (2013) A concept map-embedded educational computer game for improving students' learning performance in natural science courses. *Computers & Education* 69: 121–130.

Johnson RT and Johnson DW (1986) Action research: Cooperative learning in the science classroom. *Science and Children* 24(2): 31–2.

Jones C, Ramanau R, Cross S, et al. (2010) Net generation or digital natives: Is there a distinct new generation entering university? *Computers & Education* 54(3): 722–32.

Kapitanoff SH (2009) Collaborative testing: Cognitive and interpersonal processes related to enhanced test performance. *Active Learning in Higher Education* 10(1): 56–70.

Karpicke JD (2012) Retrieval-based learning: Active retrieval promotes meaningful learning. *Current Directions in Psychological Science* 213(3): 157–63.

Karpicke JD and Blunt JR (2011) Retrieval practice produces more learning than elaborative studying with concept mapping. *Science* 331(6018): 772–75.

Kirschner F, Paas F, Kirschner PA, et al. (2011) Differential effects of problem-solving demands on individual and collaborative learning outcomes. *Learning and Instruction* 21(4): 587–99.

Kwon SY and Cifuentes L (2009) The comparative effect of individually-constructed vs. collaboratively-constructed computer-based concept maps. *Computers & Education* 52(2): 365–75.

Liu PL, Chen CJ and Chang YJ (2010) Effects of a computer-assisted concept mapping learning strategy on EFL college students' English reading comprehension. *Computers & Education* 54(2): 436–45.

Majerich D, Stull J, Varnum S and Ducette J (2011) Facilitation of formative assessments using clickers in a university physics course. *Journal of E-Learning and Learning Objects* 7: 11–24.

Margaryan A, Littlejohn A and Vojt G (2011) Are digital natives a myth or reality? University students' use of digital technologies. *Computers & Education* 56(2): 429–40.

Mayer RE, Stull A, DeLeeuw K, et al. (2009) Clickers in college classrooms: Fostering learning with questioning methods in large lecture classes. *Contemporary Educational Psychology* 34(1): 51–57.

Mobile Fact Sheet (2017) *Pew Research Center: Internet, Science & Tech*. http://www.pewinternet.org/fact-sheet/mobile/ (accessed 19 July 2017).

Nesbit JC and Adesope OO (2006) Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research* 76(3): 413–48.

Nguyen L, Barton SM and Nguyen LT (2015) IPads in higher education – Hype and hope. *British Journal of Educational Technology* 46(1): 190–203.

Novak JD (1985) Metalearning and metaknowledge strategies to help students learn how to learn. In: West LHT and Pines AL (eds) *Cognitive Structure and Conceptual Change*. Orlando, FL: Academic Press, pp. 189–209.

Novak JD and Cañas AJ (2006) *The theory underlying concept maps and how to construct them* (Report No: CmapTools 2006-01). Florida Institute for Human and Machine Cognition. Available at: http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMaps.pdf

Novak JD and Gowin DB (1984) *Learning How to Learn*. New York: Cambridge University Press.

Novak JD and Musonda D (1991) A twelve-year longitudinal study of science concept learning. *American Educational Research Journal* 28(1): 117–53.

Novak JD, Gowin DB and Johansen GT (1983) The use of concept mapping and knowledge vee mapping with junior high school science students. *Science Education* 67(5): 625–45.

Quinn HJ, Mintzes JJ and Laws RA (2003) Successive concept mapping. *Journal of College Science Teaching* 33(3): 12–16.

Patterson B, Kilpatrick J and Woebkenberg E (2010) Evidence for teaching practice: The impact of clickers in a large classroom environment. *Nurse Education Today* 30(7): 603–07.

Redford JS, Thiede KW, Wiley J, et al. (2012) Concept mapping improves metacomprehension accuracy among 7th graders. *Learning and Instruction* 22(4): 262–70.

Reiser RA and Dempsey JV (2002) Trends and issues in instructional design and technology. In: Reiser RA and Dempsey JA (eds) *A History of Instructional Design and Technology*. Upper Saddle River, New Jersey: Merrill/Prentice Hall.

Stoyanova N and Kommers P (2002) Concept mapping as a medium of shared cognition in computer-supported collaborative problem solving. *Journal of Interactive Learning Research* 13(1): 111–33.

Totten S, Sills T, Digby A, et al. (1991) *Cooperative Learning: A Guide to Research*. New York: Garland.

Trees AR and Jackson MH (2007) The learning environment in clicker classrooms: Student processes of learning and involvement in large university level courses using student response systems. *Learning, Media and Technology* 32(1): 21–40.

Weinstein CE and Mayer R (1986) The teaching of learning strategies. In Wittrock MC (ed.) *Handbook of Research on Teaching.* New York: Macmillan, pp. 315–27.

Wolter BHK, Lundeberg M, Kang H and Herreid CF (2011) Students' perceptions of using personal response systems ("clickers") with cases in science. *Journal of College Science Teaching* 40(4): 14–19.

Wood WB (2004) Clickers: A teaching gimmick that works. *Developmental Cell* 7(6): 796–97.

Yang SC and Liu SF (2005) The study of interactions and attitudes of third-grade students' learning information technology via a cooperative approach. *Computers in Human Behavior* 21(1): 45–72.

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