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Formative Assessment of Meaningful Learning in IS Education Using Concept Mapping

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Abstract

Information Systems (IS) education needs to focus on meaningful learning because it is essential in cultivating students' problem solving and critical thinking skills. In formative assessment of the meaningful learning, we need to provide feedback to guide and enhance learning. In this study, we propose a conceptual model of meaningful learning. The model justifies the values of Concept Mapping (CM) as a formative assessment tool because of its effective dual role as both assessment artifact and communication artifact. The model suggests four potential feedback focal areas for effective feedback. We conducted preliminary experiments to validate CM's utility as a communication tool. The CMs constructed by the students provide new lens for instructors to gauge students' meaningful learning, and, more importantly, to provide detailed and precise feedback on students' learning effectiveness. The major contribution is the adaptation of a widely used thinking tool for meaningful learning and its assessment in IS education, which is validated by models based on learning theories and cognitive science.

Keywords: Concept mapping, meaningful learning, formative assessment, feedback, cognitive structure, IS education.

1. INTRODUCTION

In a survey (PayScale.com, 2016) regarding the employment preparedness of recent college graduates, hiring managers have identified Critical Thinking (CT) and Problem Solving as the most lacking soft skills. Higher education has been continuously working on the solutions to this common problem. For example, the ACM & AIS Curriculum Guidelines (Topi et al., 2010) for Undergraduate Degree Programs in Information Systems (IS) lists CT as one of the five foundational knowledge and skills. Studies (Mayer, 2002) have shown that CT skills are essential in meaningful learning, and can thus be effectively acquired and enhanced through it. Furthermore, deep and applicative apprehension resulting from meaningful learning is also crucial for the other foundational IS knowledge and skills identified by the ACM & AIS Guideline, such as leadership and collaboration, communications, and negotiation. As a result, IS educators should strategize how to understand and assess meaningful learning and in turn to promote it, so IS graduates can become more hirable.

Meaningful learning takes place when one integrates new concepts and propositions with

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existing relevant knowledge in some substantive ways, within her cognitive structure (Ausubel, 1963). Meaningful learning is an iterative process in which a learner must continue to refine, rectify, rearrange, and reorganize the content and structure of her knowledge so that her cognitive structure improves. Though idiosyncrasy exists in individual concept structures, there is usually sufficient commonality and isomorphism in individual meanings that allow communication and sharing. Therefore, being able to communicate and share knowledge in one's cognitive structure is the key to understand and assess meaningful learning (Novak, 1993).

In education, we often use summative assessment and formative assessment for learning (Scriven, 1967). Both assessments make some judgements according to certain standards, goals, and criteria (Taras, 2005). Formative assessment requires effective and continuous feedback as indicators of the gap between the actual understanding and the required standards. It should also provide direction and suggestion to bridge the identified gap. Therefore, formative assessment should provide ongoing feedback on students' performance so that instructors can continuously improve their teaching and students can improve their learning (Sadler, 1998). In this work (Nicol & Macfarlane-Dick, 2006), feedback is defined as the "information about how the student's present state (of learning and performance) relates to learning goals and the standards that defining the goals (p.2)". Studies show that effective feedback leads to learning gains across all domains, on different types of knowledge and skills, and at various levels of education (Black & Wiliam, 1998; Crooks, 1988; Fraser, 1987). Historically, we view students' learning as a simple acquisition process based on teacher transmission. Recent development, on the other hand, recognizes that learning is a process whereby students actively construct their own knowledge and skills (Barr & Tagg, 1995). In effective learning, students should interact with subject matter, transform, and communicate it to internalize the meaning and to make connections to previous-known content. Correspondingly, researchers have modified the "transmission view" of formative assessment (Boud, 2000; Yorke, 2003) and recommend best practice as follows. First, students need to be included and empowered in the assessment process (Boud, 2000); Second, students need to be able to understand the feedback messages to improve learning (Higgins, Hartley, & Skelton, 2001); Third, educators should realize that motivation and beliefs regulate the effectiveness of feedback messages, therefore, influence how students actually learn (Dweck, 2000; Garcia, 1995).

As IS educators, we are keen to devise an effective formative assessment mechanism of meaningful learning. The center of the proposed mechanism in this paper is Concept Map (CM). Our study focuses on research questions as follows: (1) What theories and models help validate CM's utility in assessing meaningful learning? (2) What assessment tools can we build around CM to assess meaningful learning? (3) What are the best practices in communicating constructive feedback on CMs to help students improve learning? (4) What is students' general perception toward using CM for learning? The major contributions of this work include: (1) We propose a conceptual model to understand and validate the potential role of CM in assessment of meaningful learning; (2) We identify focal areas to provide feedback based on our experiments; and (3) We make recommendations/guidelines for other educators who are interested in practicing CM-based teaching and learning in IS. The rest of the paper is organized as follows. In Related Work, we present relevant theoretical and empirical work. In Conceptual Model, we propose a high-level model justifying why CM is a perfect candidate for assessing meaningful learning. In the following section, we summarize our experiments and provide insights. We then provide our recommendations for potential practitioners, followed by a section pointing out limitations and future research directions.

2. RELATED WORK

Novak and Gowin (1984) introduced Concept Maps (CM) as a graphical tool for representing knowledge structure in the form of a graph (Novak & Gowin, 1984). The nodes of the graph represent concepts. The edges that run between concepts represent relationships. Concepts and relationships between them formulate propositions. The simplicity of constructing a CM makes it an easy tool for anyone to represent her knowledge structure so others could see and understand (Cañas et al., 2004). To construct a CM, one constantly integrate newly acquired concepts and relationships into existing CMs, and the structures of the CMs need to be modified, corrected, and refined to accommodate the new understanding. The continuous iterative process of such integration mimics meaningful learning rather than rote learning. There are also other factors making CM an excellent candidate as

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assessment tool of meaningful learning, summarized as follows. First, CM is an easy to learn and apply technique, which means little cognitive overhead to teaching and learning. Second, CM has solid underlying theories(Novak & Cañas, 2008). Third, software support such as CmapTools to construct and share CM is readily available and free (Cañas et al., 2004). Fourth, CM is a versatile tool that unifies the learning and assessment loop, as explained in The Conceptual Model section.

CMs have been widely adopted in many disciplines (Weideman & Kritzinger, 2003). However, its application in IS education is relatively scarce, many of which do not focus on using CM for assessment of learning systematically (Gregoriades, Pampaka, & Michail, 2009). Even in the studies that CM is used for assessment, the scope is narrowed to a limited scope of IS-related concepts such as telecommunication and networks (Freeman & Urbaczewski, 2001). The IS education community has a wide range of assessment tools, many of which have been proven effective in certain aspects, to some degree. Standard test questions such as multiple choice and T/F may be good at assessing "know-what"—usually results of rote learning. On the contrary, meaningful learning addresses "know-why" and "know-how". We often use writing assignments, hands-on projects, and case studies for those. However, the deliverables of these assignments have limited effectiveness in representing the cognitive processes and structures, which are important to understand the meaningful learning involved. The graphical structure of CMs can fit in this void.

As higher education becomes more accessible, educators are facing increasing resource constraints. As stated by Gibbs and Simpson, we are dealing with larger class sizes which makes it hard to conduct enough formative assessment to facilitate learning (Gibbs & Simpson, 2005). Sufficient and effective feedback is often simply not provided. This is detrimental to the overall teaching and learning quality. Therefore, we are in the need of an easy-to-implement formative assessment tool that also facilitates necessary feedback mechanisms in a meaningful manner. In fact, the Eberly Center of Teaching Excellence & Educational Innovation at the Carnegie Mellon University (Eberly Center, 2015) names CM as an example of formative assessment methods.

In this study, we focus on how CM can be used in various ways as formative assessment tool in IS education, as well as a tool to help instructors provide feedback to students. We summarize the overall rationale of this work in the form of a CM in Figure 1.

3. THE CONCEPTUAL MODEL

To better understand the relationships between meaningful learning, formative assessment, and communication through feedback, we construct a conceptual model as seen in Figure 2.

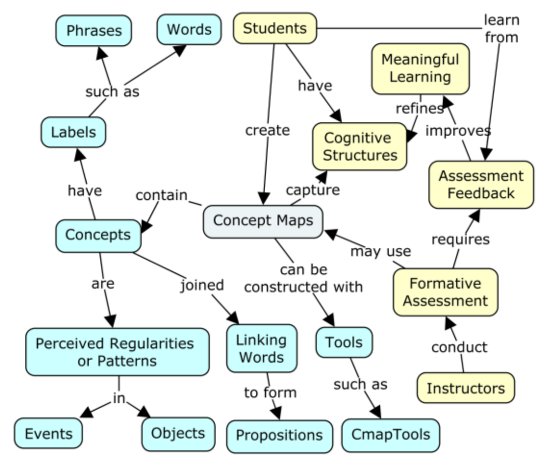

Figure 1. Using CM for Formative Assessment and Feedback

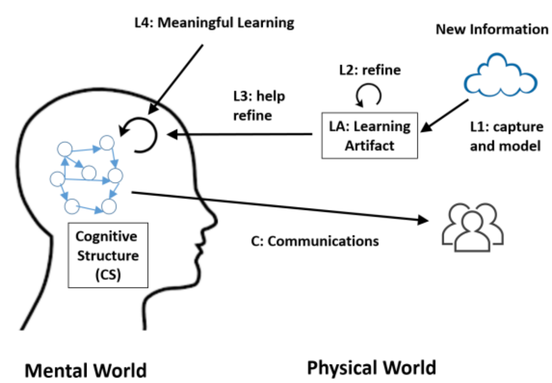

Figure 2. Concept Map and Meaningful Learning

In this model, learning (L4) is only meaningful when one actively uses new information to refine her Cognitive Structure (CS). New information continues to be assimilated into the CS. Learning Artifacts (LA) facilitate the learning processes that often consists of: (1) L1: the initial construction of a LA to understand, model, and assimilate new information; (2) L2: iteratively refinement of the LA; (3) L3: using the refined LA

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to refine CS, which is the essence of meaningful learning. In Figure 2, the LA is CM, but it can also be whatever that aids learning, including personal notes. The result of learning is the modified CS, which the learner communicates through some Communication Artifacts (CA) for various purposes, including assessment.

The communication process can be characterized by three steps as seen in Figure 3: (1) C1: synthesize knowledge in CS to construct an initial CA using a communication tool; (2) C2: the CA can be refined iteratively; (3) C3: the resulting CA is used to communicate with external entities such as instructors and peers. In Figure 3, the CA is CM, but it can be any tool that aids communications such as PowerPoint slides or videos.

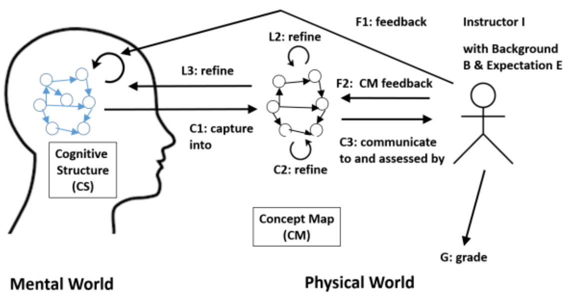

Figure 3. Concept Mapping and Assessment

Note that LA and CA have different purposes. An effective LA may not be an effective CA, and vice versa. For example, writing highly condensed (and cryptic) personal notes may be a very effective learning tool for the author, but not others, and they may not be a good communication tool. Furthermore, the sole target of learning is the refinement of the CS. In contrast, there are many types of communications, depending on the communication goals and targeted audiences. In the context of education, three kinds of communications are especially important: (1) collaborative problem solving, (2) assessment, and (3) self-communication to enhance understanding, such as by using the State, Elaborate, Exemplify and Illustrate (SEE-I) in critical thinking (Nosich, 2011). A CA may be effective for one kind of communication, but not the others. For example, UML may be effective in collaborative problem solving in software development, but not effective for a marketing presentation.

In this study, we emphasize that CM can be used effectively as both LA and CA. The ability to use CM as a common tool for both learning and communications provide synergy as we can integrate the learning and communication process. In addition, unlike other tools, the graphical nature of CM closely mimics the CS. This facilitates L3, refinement of the CS. Furthermore, communications using CM as the CA usually involve the direct capture of knowledge stored in CS (step C1). Note that CS is immensely larger than CM. CM usually contains ten of nodes. CS contains many, many concepts, with different degrees of relevance to the focus question of the CM. Finally, CM is a versatile tool for many kinds of communications, including collaborative problem solving, self-communication, and both formative and summative assessment.

In assessment, students communicate with the instructor (C2) and the instructor evaluates the shared meaning developed during the communication. The students apply their knowledge in their CS to produce Assessment Artifacts (AA), which is a form of CA. The instructor I, with background B and expectation E, then assesses the AA in order to: (1) generate a grade G (summative assessment), and (2) provide feedback F, which the students can use to refine their CS (formative assessment). As seen in Figure 3, when using CM for assessment, the instructor can provide two kinds of feedback. Direct feedback (F1) helps students directly refine their CS (L4) in a way similar to other AA. Feedback on the CM (F2), instead, focuses directly on how the students can improve their submitted CM (step L2). F2 may also be comments to highlight the difference between the submitted CM and the master key CM developed by the instructor, which measures the gap between students' understanding and the desired learning outcomes. Using the same tool, i.e., CM that resembles the CS, as both CA and AA tightens the learning and assessment loop.

4. USING CM TO ASSESS MEANINGFUL LEARNING

The work presented in this paper is a continuation to a series of studies on how to enhance learning and critical thinking in IS education. CM emerged as a promising tool during our research. We summarize several key findings from previous studies (both qualitative and quantitative) as follows (Wei & Yue, 2016a, 2016b, 2017). First, students in general find CM an easy to learn and use technique. This is true partly because for students, constructing a CM signifies a typical learning process and they found it natural. In addition, there are few norms for them to follow in the construction. Furthermore, we provide students CmapTools (Cañas et al., 2004) as the software tool to easily draw, store, manage, and export the CMs. CmapTools is free for educational purposes. Researchers in Florida Institute for Human and Machine Cognition (IHMC) developed it based on their years' research on knowledge representation. Second, students who participated the experiments in general have very positive perception toward CM's usefulness in learning and teaching, especially in stimulating critical thinking (n=112). Third, there are multiple ways of incorporating various types of CM-based teaching and learning tasks into a typical IS curriculum. Fourth, we have developed and applied tools and techniques to evaluate (both qualitatively and quantitatively) the quality of CMs completed by students.

Based on prior results, we would like to develop deeper understanding of meaningful learning and how to effectively promote it in IS education, by using CM as the medium for both communication and assessment purposes. Therefore, based on prior success of using CM in IS courses, we conducted small-scale pilot studies. Over three semesters' period (FA 15 to FA 16), we designed and incorporated CM-based teaching and learning activities into four courses in Computer Information Systems (CIS) program at UXYZ. The chosen courses cover two topics—Database Management Systems as the practical component and IS Theories as the theoretical component, at both undergraduate and graduate levels.

Experiment Setting

A major type of CM-based work for students is to ask them to construct CMs given different starting points: (1) With or without a "focus question" (Derbentseva, Safayeni, & Cañas, 2007). A focus question provides a focal point for the learners to acquire, structure, and assimilate a topic of knowledge. The CMs constructed accordingly should contain relevant concepts and their connections should be meaningfully organized to answer the focus question; (2) With or without an initial "part of CM", the "part" may include a small set of concepts (separated or structured in scaffold with relationships). Instructors provided introductory information and practice of constructing simple CMs. Then students have to complete the CM tasks as take home assignments using CmapTools. Instructors graded submitted CMs. In addition, instructors distributed questionnaires to collect and understand students' perception of CM and its utility in learning.

Quantitative Assessment

Instructors graded students' CMs and assigned an overall quantitative score as an indicator of the goodness of the work, by using a formula based on the methods introduced in (McClure, Sonak, & Suen, 1999) contrasting the student work with a "master CMs" created by the instructors. Though the scores inevitably are somewhat subjective (based on the grader's background and expectation), the general conclusion is that CM can capture the part of student's CS that is related to the specified domains/topics. The overall quality of the CM correlates with students' learning effectiveness. Thus, it can be used effectively for summative assessment. However, the grades by themselves do not provide effective formative feedback. The best they could get from the results is whether their work is up to the standards imposed by the instructors. We argue, what is the most valuable for the students should include feedback on: What is wrong? Why is it wrong? and, How to improve? These feedbacks cannot be quantified and need to be systematically provided.

Qualitative Assessment

Realizing the limitation of assigning a numeric grade to CM, we continued with new, more in-depth qualitative assessment. The purpose is to identify what types of feedback to provide on students' CMs. To illustrate this process, we use sample student CMs (as seen in Figure 4 in Appendices) as examples. For discussion purpose, we focus on the CM from IS theory class. The students were asked to construct a CM with the focus question "What are the ethical and social issues associated with IS?" The instructor gave the students 20 concepts to start with. Due to the limit of space, we list only a part of the feedback (targeting areas numbered 1-5 of the CM in Figure 4) in Table 1.

1	**Feedback to Student:** "Data" is not equivalent to "Information". Information is processed data. **Explanations:** This is an instance of incorrect relationship. It also suggests misconception of "Data" or "Information" or both. (Subject Matter)
2	**Feedback to Student:** What are the "Ethical Principles" we covered in class? **Explanations:** This is an instance of missing important concepts. It suggests possible insufficiency of content coverage in teaching. (Subject Matter)

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3	**Feedback to Student:** Do you think "Profiling" pose threats to "Privacy"? **Explanations:** This is an instance of missing important relationships.
4	**Feedback to Student:** "Copyright", "Patents", and "Trade Secrets" are types of "Intellectual Property". "Music" and "Designs" are products of intellectual work that may or may not be filed as "Intellectual Property". **Explanations:** This is an instance of inappropriate relationship. Often this is caused by misconception and/or confusion, both should be rectified.
5	**Feedback to Student:** "Patents" and "Copyright" are not "Laws". There are laws to protect patents and copyright. **Explanations:** This is an instance of inaccurate proposition.

Table 1. Sample Feedback to Students' CMs

Based on our proposed model, plus the empirical study conducted on real CMs created by IS students, we identified four major feedback focal area (FFA), or categories, for effective formative assessment. We illustrate each of the focal areas with sample feedbacks on DBMS CMs as follows. The techniques used by the instructors to construct the feedback include: (1) directly point out the deficiencies; (2) demonstrate them by highlighting the difference between the student's CM and the master CM; (3) use examples if applicable.

Table 2. Sample Feedback to CM Errors in Cognitive Structure

Misconception Type: Missing important concept. **Feedback:** Concepts like "database process", "relation schema", "relation instance" are missing.
Misconception Type: Missing important relationship. **Feedback:** The relationship between "tuple" and "attribute" is missing.
Misconception Type: Incorrect proposition. **Feedback:** The proposition "Pure DB cannot take null" is incorrect. For the pure relational model, null is acceptable.
Misconception Type: Inaccurate proposition. **Feedback:** The proposition "MS Access is a query language" is not accurate. MS Access is an example of DBMS, and it supports SQL, a query language.
Misconception Type: Incorrect relationship. **Feedback:** "Relations" "are subsets of" "Cartesian Product" is not a correct relationship.
Misconception Type: Inappropriate proposition. **Feedback:** "Candidate key" "makes up" "superkey" is not appropriate. A candidate key is also a superkey, but it does not "make up" a "superkey".
Misconception Type: Incorrect example. **Feedback:** You list "Excel" as "an example of" "a table" in the relational model. It is not. (An Excel table is based on a two-dimensional array and is not set-theoretic.)

(1) The Cognitive Structure (CS): the instructor focuses on finding strengths and weaknesses in students' CS as reflected by the CM. Instructors directly point out incorrect, incomplete, or inaccurate conceptions of the subject. The focal area is on the process L4 of Figure 3, or directly refining the student's cognitive structure. Since subject matter is usually the core concern of a class, this is a crucial focal area. When CS is the focal area, the feedback focuses on errors in the CM that reflect the misconceptions in one's CS. The misconceptions often manifest in several typical types of errors, as illustrated by the examples in a database course in Table 2, where students were asked to construct CMs to capture different topics of relational databases in various homework assignments (as seen in Figure 5). The misconceptions identified provide instructors rich insights as to how students have constructed their knowledge around the subject matter, what are the areas/topics that need more follow-up and illustration to correct the misconceptions.

(2) Concept Map (CM): In the context of assessment, CM is just a communication tool, with its shares of rules, guidelines, and best practices that can be quite rich as it is widely researched in general. A student may understand a topic well but cannot properly construct CM to model his understanding. As a result, his CM may not be of high quality. This focal area is on L2 of Figure 3, i.e., how to refine the CM using proper conceptual mapping techniques. The feedback concentrates on commenting on students' capability in coming up with quality CMs, which requires efforts (Cañas, Novak, & Reiska, 2015). It may seem that this area has no direct relevance to students' learning of subject matter, we argue otherwise. This is because CM proficiency could enhance learning in general since it is a versatile tool. This is especially true if CM is systematically embedded in learning. We present examples of feedback in the database courses for this area in Table 4 in Appendices.

(3) Capturing (C1): This is the process C1 in Figure 3 in which the CM captures CS for communications. There are actually two aspects in constructing the CM. Capturing or modeling is inward looking and focuses on whether the CM successfully capture the essence of CS on a specific focus question. It is concerned with correctness, accuracy, precision, and completeness of the CM in representing the CS. Many intellectual standards in thinking and

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modeling, such as those by the Foundation of Critical Thinking (Elder & Paul, 2007; Nosich, 2011) may be applicable here. This focal area is the process of actual capturing and representing one's CS into CM. As illustrated by the examples in Table 5 in Appendices, we focus on students' capability of creating correct, precise, accurate, and comprehensive concepts, relationships, propositions, and structures to represent his/her CS.

(4) Communications: This FFA targets the process C2 in Figure 3. As a CA, CM does not only need to model the understanding in the CS. It will also need to focus outwardly to the targeted audiences, or whether the CM effectively communicates with the audiences with some Background B and Expectation E. This is the part of story-telling. In this aspect, CM is a visualization tool for good story-telling of the CS on a topic. To communicate effectively, CM constructor needs to decide on what to include in the CM, as well as what not to include to keep the story simple, coherent, interesting, and effective. This process requires substantial amount of critical thinking. Both background B and expectation E provide the context of the feedback. For example, a feedback may be "You have not provided an example of X. It may be helpful to add a couple of examples of X as nodes in your CM as the audiences may not have concrete ideas of what X is." Alternatively, it may also be "You provide seven examples of X and your CM becomes too crowded." In fact, if the background B of the audiences include a good understanding of X, then no example of X is needed in the CM. This focal area takes a more holistic point of view as seen in the examples in Table 6 in Appendices, i.e., whether the overall CM tells a "good story". The assessment and provided feedback may be subjective as there are many ways to effective communications. But the feedback still gives students ideas as to how to improve the overall quality of the work, and in turn create opportunities for students to ponder related subject matter.

In summary, the four FFA targets four main processes in the CM-based learning and assessment loop in Figure 3: L4, L2, C1 and C2 respectively. The perceived benefits of classifying feedback into four focal areas are as follows: (1) Allow the students to understand what kinds of improvements to make by each kind of feedback; (2) Allow the instructors to provide more effective feedback based on the student learning outcomes of the assignments. The instructor should make her call as to the amount of feedback to provide and what focal areas to cover based on several factors. For example, the amount of time and work required in providing feedback should not be prohibitive. Also, certain areas could be emphasized more to reflect the expected learning outcomes of the CM assignment.

5. FINDINGS AND RECOMMENDATIONS

Prior experiment results show that students have very positive attitude toward the usefulness and utility in learning in general (Wei & Yue, 2016b). In order to answer the research question "What is the students' general perception toward using CM for meaningful learning?" with depth, we designed and distributed an open-ended questionnaire at the end of Fall 2016 to an undergraduate IS class, as a small scale pilot study. The class had been exposed to various CM-based assignments throughout the semester before the survey. Half of the class (n=11) voluntarily completed the questionnaires. Following the grounded theory approach (Corbin & Strauss, 1990), we coded the response transcript and extracted many concepts and formed constructs of different hierarchies and categories. Despite the small sample size, the results are very interesting and insightful. We summarize the high-level findings of the survey in Table 3. For each of the listed categories, there are above 90% (10 out of 11) of the participants have made statements conforming to it.

Categories	Sub-Categories	Codes
CM is useful	Useful for learning	Identify concepts
		Create relationships
		Organize knowledge
		Visualize knowledge
		Simplify learning
	Useful for teaching	Enhance classroom discussion
		Help identify misconception
		Enhance classroom instruction
	Facilitate collaboration	Good for group work
		Easy to share
		Encourage communication
	Can be versatile	Useful in education
		Useful in research
		Useful for business
CM is easy to use	Easy to learn	Short learning curve
		Quick to start
		Few norms to follow
	Easy to construct	Tools are available
		Tools are easy to use

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		Tools have good features
Intention to use CM more	Encouraged by instructor	Need more instructions
		Need more feedback from instructors
	Need buy in from peers	Team members should agree with using CM
		Peers need to cooperate
	Need better support	Better software
		CMs are in general time consuming

Table 3. Summary of Survey Results

In addition, the results help us identify what can be used to guide instructors in the efforts of proving useful feedback on CM as follows. First, students consider useful and in-time feedback from instructor important in using CM as a learning tool. Second, students identify CM as an effective assessment tool when instructors identify misconception and provide learning diagnostics.

To those who are interested in adopting CM as assessment tool of meaningful learning in IS education, we summarize our work in the recommended workflow as seen in Figure 6 in Appendices.

6. CONCLUSIONS AND FUTURE RESEARCH

In our series of studies, we focus on utilizing CM as an effective teaching and learning tool in IS education. In this work, we propose a conceptual model to understand CM's value as Learning Artifact, Communication Artifact, and Assessment Artifact. In addition, based on our previous empirical work, we make recommendations on how feedback should be provided on students' CMs to maximize improvement in students' meaningful learning. Students' perception of CM as a learning tool is also very positive. We strongly feel that our work can benefit IS educators who are interested in adopting new techniques/tools to enhance teaching and learning, in both managerial/organizational and technical IS courses. This is especially true because of the flexibility of CM and the wide range of ways to adopt and adapt it to individual needs.

Our future research activities will continue to: (1) Expand our experiments to a wider range of IS courses, at a larger scale. This would require instructors' buy in; (2) With more students' work accumulated, we could improve our feedback system; (3) Conduct the students' perception survey on a bigger scale to thoroughly understand what may promote or prohibit their adoption of CM for learning; (4) Use the survey results to establish a model for CM adoption in IS education in general; (5) Conduct quantitative studies using questionnaire created based on the CM adoption model.

9. REFERENCES

Ausubel, D. P. (1963). The psychology of meaningful verbal learning. Oxford, England: Grune & Stratton.

Barr, R. B., & Tagg, J. (1995). From teaching to learning—A new paradigm for undergraduate education. Change: The magazine of higher learning, 27(6), 12-26.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. Assessment in Education: principles, policy & practice, 5(1), 7-74.

Boud, D. (2000). Sustainable assessment: rethinking assessment for the learning society. Studies in continuing education, 22(2), 151-167.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., . . . Carvajal, R. (2004). CmapTools: A knowledge modeling and sharing environment. Paper presented at the Concept maps: Theory, methodology, technology. Proceedings of the first international conference on concept mapping.

Cañas, A. J., Novak, J. D., & Reiska, P. (2015). How good is my concept map? Am I a good Cmapper? Knowledge Management & E-Learning: An International Journal (KM&EL), 7(1), 6-19.

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. Qualitative sociology, 13(1), 3-21.

Crooks, T. J. (1988). The impact of classroom evaluation practices on students. Review of educational research, 58(4), 438-481.

Derbentseva, N., Safayeni, F., & Cañas, A. (2007). Concept maps: Experiments on dynamic thinking. Journal of Research in Science Teaching, 44(3), 448-465.

Dweck, C. S. (2000). Self-theories: Their role in motivation, personality, and development: Psychology Press.

ISSN: 2473-3857
v3 n4312

Eberly Center. (2015). What is the difference between formative and summative assessment? Whys & Hows of Assessment. Retrieved from https://www.cmu.edu/teaching/assessment/basics/formative-summative.html

Elder, L., & Paul, R. (2007). The Thinker's Guide to Analytic Thinking: How to Take Thinking Apart and what to Look for when You Do: the Elements of Thinking and the Standards They Must Meet (Vol. 16): Foundation Critical Thinking.

Fraser, B. J. (1987). Identifying the Salient Facets of a Model of Student Learning: A Synthesis of Meta Analyses. International Journal of Educational Research, 11(2), 187-212.

Freeman, L., & Urbaczewski, A. (2001). Using Concept Maps to Assess Students' Understanding of Information Systems. Journal of Information Systems Education, 12(1), 3-9.

Garcia, T. (1995). The role of motivational strategies in self-regulated learning. New directions for teaching and learning, 1995(63), 29-42.

Gibbs, G., & Simpson, C. (2005). Conditions under which assessment supports students' learning. Learning and teaching in higher education(1), 3-31.

Gregoriades, A., Pampaka, M., & Michail, H. (2009). Assessing Students' Learning in MIS using Concept Mapping. Journal of Information Systems Education, 20(4), 419.

Higgins, R., Hartley, P., & Skelton, A. (2001). Getting the message across: the problem of communicating assessment feedback. Teaching in higher education, 6(2), 269-274.

Mayer, R. E. (2002). Rote versus Meaningful Learning. Theory Into Practice, 41(4), 226-232. Retrieved from http://www.jstor.org/stable/1477407

McClure, J. R., Sonak, B., & Suen, H. K. (1999). Concept map assessment of classroom learning: Reliability, validity, and logistical practicality. Journal of Research in Science Teaching, 36(4), 475-492.

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. Studies in higher education, 31(2), 199-218.

Nosich, G. M. (2011). Learning to think things through: A guide to critical thinking across the curriculum: Pearson Higher Ed.

Novak, J. D. (1993). Human constructivism: A unification of psychological and epistemological phenomena in meaning making. International Journal of Personal Construct Psychology, 6(2), 167-193.

Novak, J. D., & Cañas, A. J. (2008). The theory underlying concept maps and how to construct and use them. Florida Institute for Human and Machine Cognition, 2008.

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

PayScale.com. (2016). 2016 Workforce-Skills Preparedness Report. Retrieved from http://www.payscale.com/data-packages/job-skills

Sadler, D. R. (1998). Formative assessment: Revisiting the territory. Assessment in Education: principles, policy & practice, 5(1), 77-84.

Scriven, M. S. (1967). The methodology of evaluation (Perspectives of Curriculum Evaluation, and AERA monograph Series on Curriculum Evaluation, No. 1). Chicago: Rand NcNally.

Taras, M. (2005). Assessment: Summative and Formative: Some Theoretical Reflections. British Journal of Educational Studies, 53(4), 466-478. Retrieved from http://www.jstor.org/stable/3699279

Topi, H., Valacich, J. S., Wright, R. T., Kaiser, K., Nunamaker Jr, J. F., Sipior, J. C., & de Vreede, G.-J. (2010). IS 2010: Curriculum guidelines for undergraduate degree programs in information systems. Communications of the Association for Information Systems, 26(1), 18.

Wei, W., & Yue. K. (2016a) Using Concept Maps to Assess Students' Meaningful Learning in IS Curriculum. Proceedings of the EDSIG Conference, Las Vegas, Nevada, Volume 2, n2473, November 2016.

Wei, W. & Yue, K. (2016b) Using Concept Maps to Teach and Assess Critical Thinking in IS Education, Proceedings of the 22nd Americas Conference on Information Systems AMCIS, San Diego, California, USA, August 2016.

Wei, W., & Yue, K.-B. (2017). Integrating Concept Mapping into Information Systems Education

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v3 n4312

for Meaningful Learning and Assessment. Information Systems Education Journal, 15(2), 4-16.

Weideman, M., & Kritzinger, W. (2003). Concept Mapping-a proposed theoretical model for implementation as a knowledge repository. ICT in Higher Education.

Yorke, M. (2003). Formative assessment in higher education: Moves towards theory and the enhancement of pedagogic practice. Higher education, 45(4), 477-501.

 ISSN: 2473-3857
v3 n4312

Appendices

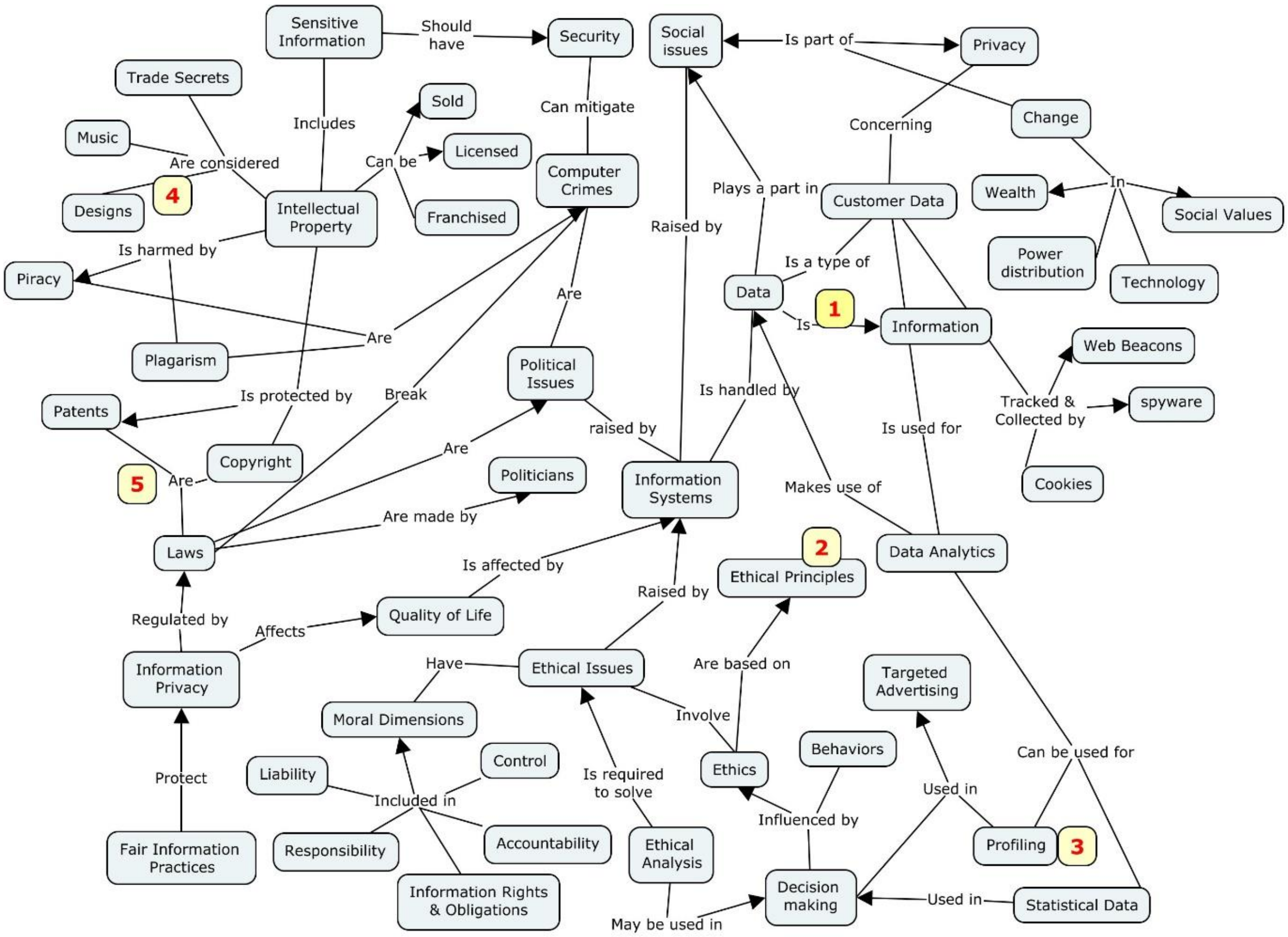

Figure 4. A Sample CM from Students in IS Theory Class

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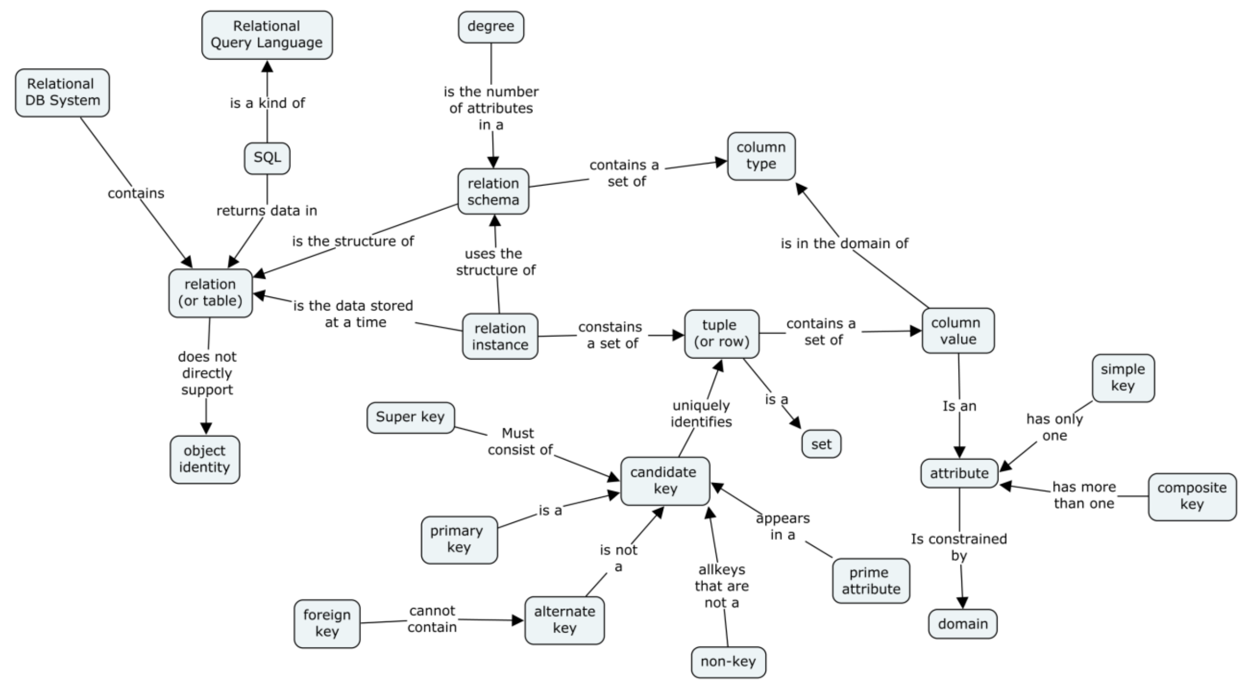

Figure 5. A Sample Student CM from a DBMS Assignment

Two or more nodes with the same name should in general be shown as one node.
You may split a node to two or more nodes if it contains many concepts.
You may use a directed edge as the direction is clear in this relationship.
Links are relationships between concepts and may not be concepts themselves. In your proposition "Database" "RDBMS" "SQL," the link "RDBMS" should better be modeled as a concept, not a link.
Nodes should model concise and distinct concepts. Your node "Requirement, Design, Implementation, Testing, Maintenance" may better be modeled as five separate concept nodes related to the waterfall model if you decide to keep them.
Nodes should in general be connected. The node "Waterfall model" is not connected to any node.

Table 4. Sample Feedback to CM Errors in CM Technique

Be specific when appropriate. By 'Pure DB,' do you mean 'Theoretical relational model.' The term 'pure' has many possible meanings.
Try to be accurate and precise. For example, in your proposition "data" "are" "concurrent," is not quite accurate. It is the access to data that can be concurrent, not data itself.
Most of your links do not have names. They need to be included to provide clear propositions to capture your understanding.
You have two nodes "a collection of relations" and "the concept of relation" and seem to understand them. However, they are compound concepts. Instead, you may have a node "relation."
To provide a more complete overview, some links need to be added, such as "is a property of" between the nodes "key" and "relation."
It seems that you understand that a relation is composed of rows. However, you have not provided an explicit link between the concept nodes of "relation" and "rows", such as "contains a set of".

Table 5. Sample Feedback to CM Errors in Capturing of CS

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Try to provide a 'big picture' overview. Example: you have concept nodes 'DML' and 'DDL', but not 'SQL'.
Good to include examples to illustrate selected concepts, such as 'DML' and 'DDL'.
Your CM has 92 nodes, which may be too complex for providing an overview. Try to remove less important concepts to provide a better focus.
Your CM has only 17 nodes, which is not sufficient to provide a fuller overview of this focus question, try substantiate it more with relevant concepts and relationships.
Your targeted audiences probably know the concept "SQL command." Anyway, it is not necessary to provide 7 examples. If needed, one or two examples will be enough.
Your node names are short and concise, which is good. However, each node should represent an unambiguous concept. Thus, use "relational model" instead of "relational", "candidate key" instead of "candidate", etc.

Table 6. Sample Feedback to Improve CM Communication

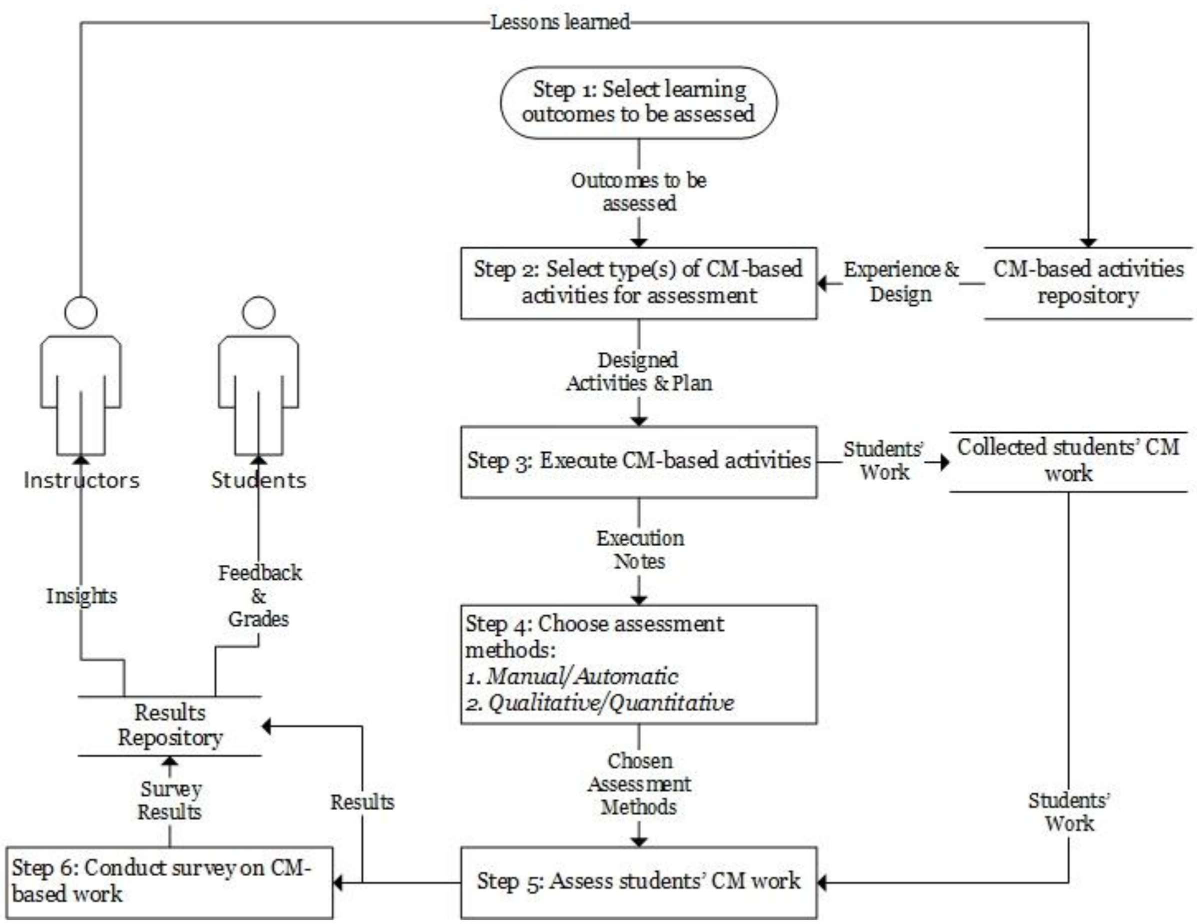

Figure 6. Recommended CM-based Assessment Workflow