# USING CONCEPT MAPPING TO ASSESS A LARGE-SCALE PROJECT

*Colleen M.Eddy, David Wojnowski, Pamela Harrell, Karthigeyan Subramaniam & Sarah Pratt*
*University of North Texas, U.S.A*
*Email: Colleen.Eddy@unt.edu*

**Abstract.** Concept maps have been used in many research studies to analyze content knowledge transformation, but very few studies examine their use in large-scale projects. The purpose of this study is to evaluate the growth of in-service teacher content knowledge across 37 professional development projects, which include over 1,000 mathematics and/or science teachers. Project directors participate in an orientation to concept maps, which provides a rationale for using them, and instruction for creating an expert C-map. During the project director training, each project director generated C-maps. The C-maps are specific to the content for each institute and align with the major project content objective. The C-maps are used as a template for the creation of S-maps, which are used as pre/post-assessment tools for the evaluation of in-service teacher content knowledge. A team of researchers including science/mathematics education faculty and academic faculty verify the C-maps and provide feedback to project directors prior to the construction of the S-map template. In addition to the concept maps, the number of content courses taken by the in-service teacher and interviews are used for purposes of analyzing teacher content knowledge.

## 1 Introduction

While concept mapping is a tool often utilized to assess misconceptions and transformations in knowledge of particular concepts in a content area, there currently are very few research projects that use concept maps as an assessment tool for larger scale studies. The vast majority of concept map research studies involve less than 100 participants (Nesbit & Adesope, 2006). In a meta-analysis that focused on the reliability and validity of concept mapping of research studies in science grades K-12, Himangshu and Cassata-Widera (2010) included only one out of 25 studies that contained over 600 participants (Schau, Mattern, & Weber, 1997). Four studies included at least 100 participants, with the remaining studies using less than 100 participants. In a brief survey of the current research, we found even fewer studies related to large-scale use of concept mapping to assess knowledge of mathematics concepts (Bolte, 1999; McGowen & Tall, 1999; Schneider & Stern, 2010). Furthermore, the authors of this manuscript have not found research studies in concept mapping to date that have addressed large-scale use of concept maps for in-service teachers.

This paper describes the development of an assessment tool to be used for large-scale projects designed to meet the evaluation needs of a state educational institution that is situated in the United States. The state institution is comprised of 37 grant awards and predominantly serves over 1,000 secondary mathematics and science teachers with a few awards focused on primary grades content.

While creating this assessment tool, the authors considered the issues of reliability and validity of scaling up the use of concept maps for large research studies. Himangshu and Cassata-Widera (2010) suggest using the select and *fill-in-the-map* (S-map) as well as the *create-a-map* (C-map) concept map techniques to support concurrent validity. The authors point out that “by their nature, ‘fill in maps’ are not designed to detect misconceptions or depict a student’s unique structure of knowledge” (p. 63). In addition, “fill in maps” may not provide opportunities for students to express personal experiences connected to the concept nor would they allow the freedom for students to make connections to a larger conceptual framework or other domains outside the particular domain.

Two other considerations with regard to the use of “fill in concept maps” in large-scale assessment studies should be addressed. The first issue has to do with the affordance of the instrument (Carey & Shavelson, 1989), that is what economic resources are available to collect and score results. The second consideration deals with the possibility of teachers teaching to the test and the consequences associated with low-level knowledge such as memorization (Shavelson, Carey, & Webb, 1990).

## 2 Model Development

### *2.1 Project Components*

In order to better understand the complexity of needs associated with evaluating the success of this large-scale project, a description of the common components of each grant is listed below. Each project requires:

- 50 hours of training during the summer to increase content knowledge for specified concepts;
- Monthly academic meetings during the school year to increase teacher effectiveness for specified concepts;
- Teachers to teach within the specified content and associated grade-level (band) assignment in order to participate in project (e.g., biology, algebra);
- A minimum of 20 teachers per institute
- All institutes must focus on the development of mathematics or science pedagogical content knowledge

### *2.2 Instrument Selection*

The state educational institution is federally funded. For the 2012-2013 award cycle, there are 37 awardees that were selected through a competitive state grant review process. The state director and the state evaluation director for all projects require a common assessment tool for the grant recipients to demonstrate teacher content knowledge change. The directors recruited the authors to design an evaluation plan for a large-scale study that would specifically measure content knowledge of mathematics and science teachers over the course of the instructional intervention.

As a result, the authors selected concepts maps as an assessment tool to evaluate in-service teacher content knowledge. Although C-maps are associated with higher validity and S-maps are associated with higher reliability, based on time and expense involved in the creation, scoring, and analysis of approximately 1,000 concept maps the use of low-directed S-maps was better suited. These maps may tap a different aspect of content knowledge compared to C-maps but still provide an acceptable technique, which can be used to measure content knowledge. The tool includes the implementation of a pre- and post-concept map assessment for all participants that were associated with the content knowledge addressed through institute objectives and using S-maps. Additionally, interviews will be used as another way to assess cognitive activity. The nature of participant verbalizations as correlated with knowledge exhibited on the pre/post concept maps will also be explored. The authors will collect the data from all 37 grant awards, analyze the data, and provide the results to the state directors at the conclusion of the evaluation period for the grant (Table 1).

| **State Director Evaluation** | **Project Director Evaluation** |
|---|---|
| Summative | Formative |
| Pre- and Post- concept maps | Pre-concept maps<br>• Mastery of concept<br>• Misconceptions<br>• Pre-planning of professional development |

**Table 1:** Purpose of Concept Maps for State Director and Project Directors

### *2.3 The Process*

The evaluation plan will involve the use of C-maps in the form of expert maps and low-directed S-maps that will constructed by the participants. The C-map program will be used for the creation of all maps. Each of the expert maps must be validated by a science/mathematics education expert and a content expert. Feedback will be provided to project directors to finalize the expert map. The research team will create S-maps within a modification of the C-map program and each participant will put these concepts and linking word/phrases together. A pre/post administration will occur at the beginning and end of the institute. The research team will conduct participant interviews. The transcripts from interviews will be used to assess the degree to which verbalizations are correlated with pre/post concept maps. An open-interview technique will be used.

#### 2.3.1 Creating the Expert Maps

The first step in the process requires that the project directors create an expert map for each of their institutes. The function of these is to use the expert maps is to create the S-map assessment tool. The expert concept map includes: (1) a main idea and (2) no more than 30 subordinate ideas. All of the concepts are either connected to the main idea or to other subordinate ideas associated with the superordinate concept.

Directors were given preparation materials prior to a 3-hour training session, which occurred over a two-day period. Each project director was provided research articles related to the construction and use of concept mapping as assessment tools to facilitate the organization of the content topic using subordinate concepts. This topic was to associate with the major project content objective (i.e., What are the profound points of understanding you want teachers to take away from your project?)

The first day of training focused on three primary questions: 1) How do we determine what teachers know? 2) How do project directors purposefully help teachers construct knowledge that is meaningful? and, 3) How do we know when teachers have mastered a concept?

With these questions guiding the training, the training of concept mapping proceeded through these main topics:

1. Definition of terms such concept, concept map, proposition, C-Concept Map, & S-Concept Map
2. What are not concept maps
3. Why use concept maps
4. Types of concept maps
5. Advantages and Disadvantages of concept maps
6. What are propositions
7. How create C-maps and S-Concept Maps
8. The Frayer Model as a tool for brainstorming
9. Cmap software
10. Training video to be shown during institute prior to pre-assessment

At the conclusion of the two-day training, the categories of concept maps were related back to the tasks of the project directors and the expert map created by the project director (Table 2).

| Project Director | In-service Teacher (Participant) |
|---|---|
| C-Concept map | S-Concept Map |
| Constructed from memory and without assistance | • Provided concepts<br>• Provided linking words and directional arrows<br>• Identification of common misconceptions<br>• Create the propositions from the provided concepts and linking words to create the concept map |

**Table 2:** The Category of Concept Map and Relation to Project

Project directors were purposefully grouped according to project content similarity. Discussion and revision were used to generate drafts for expert maps during the training. An additional three weeks would be provided in which the project directors would continue to refine the expert map prior to review by the research team.

### 2.3.2 Verifying the Expert Maps

The project directors submitted concept maps by e-mail according to their content specialization, science or mathematics education. Upon receipt of the concept map by the lead researcher, verification is made that the file can be opened and read. The file is then labeled and put into a secure server that is accessible to the research team. This includes both science/mathematics education as well as discipline faculty. Each concept map is reviewed by one education expert and one discipline expert in mathematics or science (chemistry/physics/biology/Earth science). Each expert reviews the map independently followed by a joint review. Recommendations are generated during the joint review and shared with the project director so that modifications to the expert concept map are made prior to the pre-assessment. Additionally, recommendations include misconceptions and additional linking phrases to increase the rigor of the S-maps.

### 2.3.3 Participant Concept Maps

Two training videos on concept mapping, one for mathematics and one for science, were created to establish reliability of training in concept mapping. The actual length of the video runs no longer than 10 minutes but since the video is interactive the project director is directed when in the video to stop so that the in-service teachers are able to complete an activity. For example, the in-service teachers construct an S-map on matter for science. Working in pairs the teachers create the concept map from the given concepts and linking phrases (See Figure 1). This experience is similar to what the project directors experienced in the first day of training.

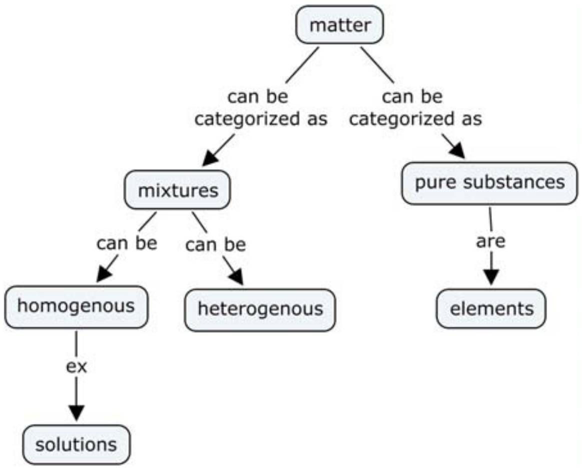


**Figure 1.** Concept map created by in-service teachers during training video.

A programmer was hired to investigate and then develop a program to score the in-service teacher's S-map against the expert map. The score generated included the number of correct propositions out of the total propositions possible as indicated on the expert concept map. Using *Figure 1* a correct proposition would be *matter can be categorized as mixtures*. No points are deducted for incorrect propositions.

The following list is an outline of events for conducting the evaluation of the large-scale project.

1. Conducting a training session on how to construct a concept map with project directors
2. Administration and analysis of pre-assessment concept maps and associated narratives of participants
3. Administration and analysis of post-assessment concept maps and associated narratives of participants
4. Administration and analysis of interviews for concept maps
5. Evaluation report

## 3 Methods

### *3.1 Sample*

The total number of participants will include ~ 1000 paired concept maps (i.e., 1000 pre- and a 1000 post-concept maps each accompanied by narrative data). Each map will include approximately 30 propositions. Approximately 20-30 participants will be interviewed. Various researchers suggest sample numbers of participants for qualitative triangulation. Cresswell (1998) suggests 20 to 30 participants per group depending on saturation of themes. Sandelowski (1995) suggests 30-50 interviews per group depending on saturation of themes.

In order to show that the qualitative analysis is representative, numerical analysis will be applied to ascertain the proportions of concept maps and narratives expressing particular themes and hence how far they are representative of the total sample (Francis, Skelton, Carrington, Hutchings, Read & Hall 2008; Silverman 1993).

### *3.2 Analysis*

We will use a thematic analysis approach to analyze concept maps and narrative data. The concept maps will be analyzed for thematic content following the analysis procedures as described by Boyatzis (1998). The narrative section explaining the participants' concept map (not a description of the concept map, but an *explanation* of the concept map – i.e., an explanation of their understanding of the superordinate concept and the connections to the subordinate concepts depicted in the concept map) will be key in the purposeful sampling of the participants that will be interviewed. We will use the standard "saturation of data" to determine the total number of interviews needed in relation to, the heterogeneity of the population; the number of selection criteria; the extent to which 'nesting' of criteria is needed; groups of special interest that require intensive study; multiple samples within one study; types of data collection methods use; and the budget and resources available (Ritchie, Lewis, &, J. & E. Gillian, 2003).

Subgroups could be initially organized around the following groups:

1. *No gains*
   a. unsophisticated conceptual knowledge on both the pre and post S-map, thus showing no gain in content knowledge.
   b. average conceptual knowledge on the pre S-maps who show no gain in conceptual knowledge as displayed by the post-concept map;
   c. sophisticated conceptual knowledge represented by their pre and post S-maps, thus disallowing a significant gain in content knowledge

2. *Average gain*
   a. unsophisticated conceptual knowledge on the pre S-maps who show an average gain in conceptual knowledge as displayed by the post S-map
   b. average conceptual knowledge on the pre S-maps who show an average gain in conceptual knowledge as displayed by the post S-map

3. *High gain*
   a. unsophisticated conceptual knowledge that show a large gain after the intervention on their post S-maps.

We will also investigate anomalies such as those that score higher on the pre-concept map than the post, as well as those that do not make any significant gains following the intervention or “treatment” (i.e., the professional development training). The background knowledge and academic history, (i.e., transcript documents) would be important data to identify as possible reasons for the gains or lack thereof.

The use of qualitative methods and analysis are appropriate for program implementation studies like the present study because qualitative research methods provide the mechanism for: (a) documenting and monitoring implementation; (b) examining the ecological or contextual fit of the intervention; and (c) guiding modifications to achieve ecological fit (Nastasi & Schensul, 2002). Thus, qualitative inquiry both permits the naturalistic study of interventions and provides a systematic data-based approach to decision making about program adaptations. Through ongoing data collection, project staff can identify what is not working, explore why it is not working, generate solutions based on this evidence, document decision making, and track the effectiveness of modifications. The careful study of adaptations provides the in-depth description that is necessary for transferring or generalizing programs to other contexts. When conducted across multiple settings, documentation of the adaptation process can lead to understanding of the program’s core elements (i.e., those that are necessary for outcomes) and development of guidelines for flexible program implementation (i.e., how to maintain integrity of core elements while permitting adaptations; Nastasi, Varjas, Schensul, et al., 2000). Furthermore, qualitative methods permit the study of unintended outcomes as well as individual variations in intended outcomes (Nastasi, 2002).

## 4 Summary

As described previously there lacked research models in concept mapping for conducting large-scale research studies especially studies that involved in-service teachers (Bolte, 1999; Himangshu and Cassata-Widera 2010; McGowen & Tall, 1999; Nesbit & Adesope, 2006; Schau, Mattern, & Weber, 1997; Schneider & Stern, 2010). This paper provided model development for assessing a large-scale project that included over 1,000 in-service teachers. How and what data was to be collected for the project as well as factors such such as time and money for the number of participants being evaluated were some of the considerations for the model development.

## 5 References

Bolte, L. (1999). Using concept maps and interpretive essays for assessment in mathematics. *School Science and Mathematics, 99* (1), 19-25.Boyatzis, R. E. (1998). Transforming qualitative information: Thematic analysis and code development (2nd ed.). Thousand Oaks, CA: Sage.

Carey, N., & Shavelson, R. (1989). Outcomes, achievement, participation, and attitudes. In R.J. Shavelson, L.M. McDonnell, & J. Oakes (Eds.), Indicators for monitoring mathematics and science education: A sourcebook (pp. 147-191). Santa Monica, CA: RAND Corporation.

Creswell, John (2007). Qualitative inquiry and research method: Choosing among five approaches (2nd ed.). Thousand Oaks, CA: Sage.

Francis, B., Skelton, C., Carrington, B., Hutchings, M., Read, B., & Hall, I. (2008). A perfect match? Pupils' and teachers' views of the impact of matching educators and learners by gender. Research Papers in Education, *23*(1), 21-36.

Himangshu, S., & Cassata-Widera, A. (2010). Beyond individual classrooms: How valid are concept maps for large scale assessment? In J. Sánchez, A.J. Cañas, J.D. Novak (Eds.), Concept Maps: Making Learning Meaningful Proc. of Fourth Int. Conference on Concept Mapping (pp. 58-65). Viña del Mar, Chile.

McGowen, M., & Tall, D. (1999). *Concept maps & schematic diagrams as devices for documenting the growth of mathematical knowledge.* Paper presented at the 23rd Annual Conference of the International Group for the Psychology of Mathematics Education, Haifa, Israel.

Nastasi, B. K. (2002). The realities of large-scale change efforts. *Journal of Educational and Psychological Consultation*, *13*(3), 219-226.

Nastasi, B., & Schensul, S. (2002, April). Qualitative methods in intervention research. In B. K. Nastasi & S. L. Schensul (Co-Chairs), *Qualitative methods in intervention research: Contributions to identification of evidence-based interventions.* Symposium conducted at the annual meeting of the American Educational Research Association, New Orleans, LA.

Nastasi, B., Varjas, K., Bernstein, R., & Jayasena, A. (2000). Conducting participatory culture-specific consultation: A global perspective on multicultural consultation. *School Psychology Review, 29,* 401–413.

Nesbit, J., & Adesope, O. (2006). Learning with concept and knowledge maps: A meta-analysis. Review of Educational Research, 76(3): 413- 448.

Ritchie, J., Lewis, J., & Elam, G. (2003). Designing and selecting samples. In J. Ritchie & J. Lewis (Eds.), *Qualitative Research Practice: A Guide for Social Science Students and Researchers* (pp. 77-108). Thousand Oaks, CA: Sage.

Sandelowski, M. (1995). Focus on qualitative methods: Sample size in qualitative research. Research in Nursing & Health, *18,* 179-183.

Schau, C. Mattern, N., & Weber, R.J. (1997). Use of fill-in-concept maps to assess middle school students' connected understanding of science. Paper presented at Annual Meeting of the American Educational Research Association, Chicago, IL.

Schneider, M., & Stern, E. (2010). The Developmental relations between conceptual and procedural knowledge: A Multimethod approach. *Developmental Psychology, 46* (1), 178–192.

Shavelson, R.J., Carey, N.B., & Webb, N.M. (1990). Indicators of science achievement: Options for a powerful policy instrument. *Phi Delta Kappan, 71,* 692-697.Silverman, D. (1993). Interpreting qualitative data. London: Sage.