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CONCEPT MAP-BASED ASSESSMENT FOR ADULT LEARNERS

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Abstract. The use of Concept Maps for assessment of learning in children has been studied extensively. Likewise, though to a much lesser extent, Concept Map-based assessment for adult learners in a training context has also been investigated. The research base suggests that Concept Map-based assessment is a valid and reliable approach for assessing learning. This study builds on previous research by using Concept Maps to assess the learning of adult military service members in the context of training for deployment into hostile regions. Specifically, the training intervention concerned the topic of Improvised Explosive Devices. Concept Mapping was employed to identify knowledge differences between service members who had extensive experience with IEDs, and those who had little or none. Areas of assessment were developed from these knowledge differences. Concept Map-based assessment items—Multiple Choice Concept Maps—focused on the areas of assessment were developed and used to test for the training impact of a learning experience. Findings indicate that the items were sensitive to changes in knowledge.

1 Introduction

The use of Concept Maps for assessment of learning in children has been studied extensively (Mintzes et al., 2000; Novak & Gowin, 1984). Borrowing from Schaal's account (2008), we can reasonably state that the "validity and reliability of concept mapping assessment has been properly explored."

To a lesser extent, the use of Concept Maps for assessment of adult learners in a training context has also been studied. Stevens' dissertation work is, to our knowledge, the only empirical study examining this issue. In the context of evaluating the learning impacts of a 40-hour training course for personnel working with hazardous waste, she found that "predrawn fill-in concept maps can be used as an alternative method for quantitatively assessing adult learning in training situations" (Stevens, 1997, p. viii).

Similar to Stevens' approach, we have a need to understand the impact of a training intervention on adult learners. Under sponsorship from the U.S. Department of Defense, we have developed an interactive, virtual training intervention for military service personnel focused on the problem of improvised explosive devices (IEDs). Our intervention—Insurgent Mindset Training (IMT)—places service personnel in a virtual gaming environment—Virtual Battlespace™ (VBS2) from Bohemia Interactive—and requires them to make decisions with regard to detecting and responding to IEDs. Our need is to evaluate the impact of this training intervention on adult learners. We have adopted an approach to assessing this intervention based on extensive use of Concept Mapping.

This paper reports on the use of Concept Mapping and Concept Maps for assessment of adult learners. A four-stage approach was adopted. First, Concept Mapping-based knowledge elicitation was employed to identify knowledge differences between service members who have had extensive, real-world experience encountering IEDs, and those who have had little or none. Next, areas of assessment were identified using the Concept Maps developed during the knowledge elicitation. Next, Concept Map-based assessment items, focused on the areas of assessment, were developed. These items were examples of a novel invention—Multiple Choice Concept Map items. The items were used to test for the impact of a learning experience—i.e., training with IMT. CmapTools was used to enable several of the stages.

This paper reports on the methodology of the four-stage approach. Because of the sensitive nature of the domain, this paper does not include specific content in any Concept Maps—only structures are shown. Where appropriate, content is described.

2 Stage 1: Concept Mapping to identify knowledge differences

In June 2010, we employed Concept Mapping with 11 service members from the U.S. Army at Fort Richardson, near Anchorage, Alaska. The goal of this stage was to identify knowledge differences between the service members, using Concept Map-based knowledge elicitation techniques (Moon, Hoffman, Novak & Cañas, in press) and CmapTools.

2.1 Concept Mapping with Experienced service members

Two researchers independently co-created Concept Maps with each of the service members. The researchers conducted one-hour sessions with four highly experienced service members ("Experienced"). Specifically, this group was comprised of service members who have served in a small unit, and have several experiences conducting mounted or dismounted patrols in which insurgent activities were discovered, IEDs were found, or IEDs were detonated.

The focus question for all sessions was "What are the features of an area where you can anticipate IED threats?" This focus question was determined by our previous work in understanding the cognitive challenges inherent in IED detection and response (Phillips, Moon, Yeager and Baxter, 2009). The question was purposefully broad-based in asking about "features of an area" in order to allow the service members to report on any features, e.g., geospatial and human.

One Concept Map was created for each Experienced service member, yielding four Concept Maps and a total of 247 propositions (i.e., concept – linking phrase – concept). The largest Concept Map included 99 propositions, the smallest 45, and the average number of propositions was 61.75.

Using techniques described by Harter and Moon (2010), we merged and organized the set of Concept Maps into one large Concept Map, which provided us with a composite look at the entire dataset of propositions, organized into themes. The composite Concept Map is shown in Figure 1. It includes 251 propositions. The propositions were organized into four themes, and color-coded. In pink are propositions related to BLUFOR, or features of the area dealing with friendly forces. Orange includes propositions related to Insurgents. Yellow are propositions regarding Terrain. And green are propositions dealing with the Local Population. The content of the propositions is not shown. To provide an example of the content, one set of propositions reads: Insurgents → have → Plans, Plans → are about → Initiation (i.e., the mechanism that initiates the explosion), Initiation → includes → command wire.

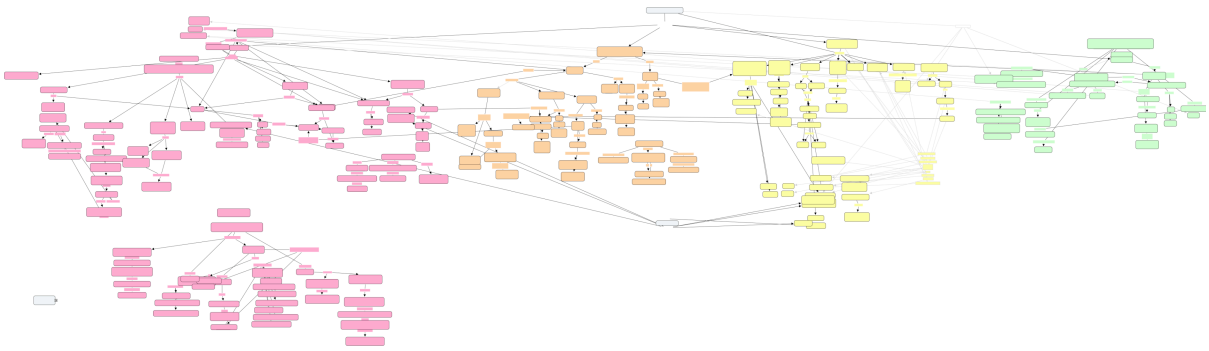

Figure 1. Composite Concept Map – Experienced Group.

2.2 Concept Mapping with lesser experienced service members

We also conducted Concept Map-based knowledge elicitation sessions with five intermediate-level experienced service members ("Intermediate"). Specifically, this group was comprised of service members who had less operational experience than the experienced performers. Finally, we conducted Concept Map-based knowledge elicitation sessions with two novice performers ("Novice"), i.e., service members with no deployment experience. The focus question for these sessions was the same as with the experienced performers.

One Concept Map was created for each Intermediate service member, yielding five Concept Maps and a total of 229 propositions (i.e., concept – linking phrase – concept). The largest Concept Map included 61 propositions, the smallest 37, and the average number of propositions was 45.8.

As with the Experienced group, we merged and organized the set of Concept Maps from the Intermediate group into one large Concept Map, which provided us with a composite look at the entire dataset. The composite Concept Map is shown in Figure 2. It includes 190 propositions. The propositions were organized into six themes, and color-coded. In pink are propositions related to BLUFOR; orange includes propositions

related to Insurgents; yellow are propositions regarding Terrain; and green are propositions dealing with the Local Population. In blue are propositions about Afghani Forces, and in purple are propositions about Locations.

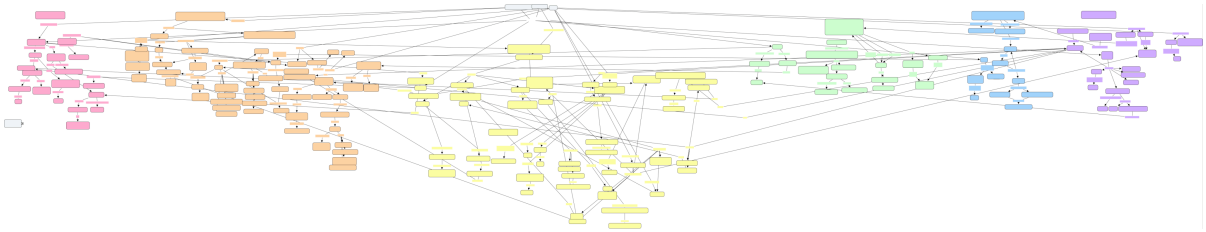

Figure 2. Composite Concept Map – Intermediate Group.

One Concept Map was created for each Novice service member, yielding two Concept Maps and a total of 62 propositions (i.e., concept – linking phrase – concept). The largest Concept Map included 40 propositions, the smallest 22, and the average number of propositions was 31.

As with the other groups, we merged and organized the set of Concept Maps from the Novice group into one large Concept Map, which provided us with a composite look at the entire dataset. The composite Concept Map is shown in Figure 3. It includes 62 propositions. The propositions were organized into five themes, and color-coded. In pink are propositions related to BLUFOR; orange includes propositions related to Insurgents; yellow are propositions regarding Terrain; in purple are propositions about Locations; and green are propositions dealing with the Local Population.

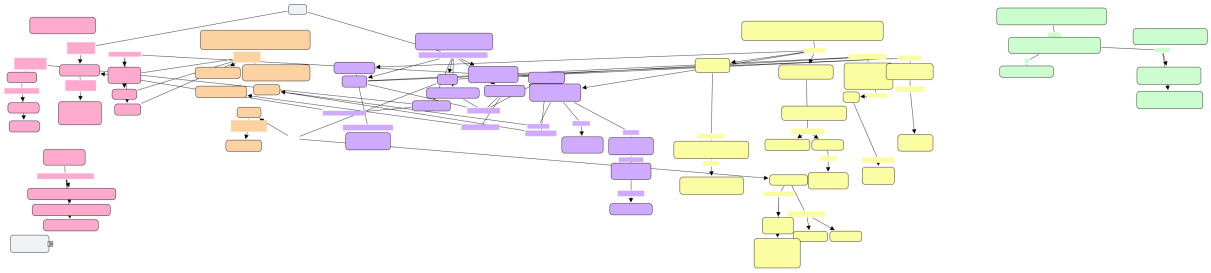

Figure 3. Composite Concept Map – Novice Group.

When the Composite Maps are viewed without the benefit of the text and at large scale, it may appear that the Experienced Group and Intermediate Group demonstrate very little difference. Deeper analysis reveals the differences, however. Table 1 presents a quantitative comparison of the Concept Maps across groups. While the total N is small, differences in the volume of propositions are noticeable. These counts lent credibility to the existence of real knowledge differences between the groups.

Propositions per Concept Maps, by experience level	**Experienced** (N=4)	**Intermediate** (N=5)	**Novice** (N=2)
Average Propositions	61.75	45.8	31
High	99	61	40
Low	45	37	22

Table 1: Propositions per Concept Maps, by experience level

In addition to the differences in the volume of propositions, significant differences in the nature of the propositions were also identified, as we discuss in the next section.

3 Stage 2: Area of Assessment development

In our next stage we compared the three composite Concept Maps to identify areas that are ripe for assessment—i.e., areas that show stark differences in knowledge between the three groups.

We conducted a qualitative comparison of the composite Concept Maps, using CmapTools. The most salient point of comparison was the emergence of similar themes. Specifically, each Concept Map included propositions dealing with BLUFOR, Insurgents, Terrain and the Local Population. The overlap in these themes lent validity to our use of the Concept Map-based knowledge elicitation approach, and lent reliability to our use of the same focus question across groups.

The Intermediate group also included Location and Afghani Forces as themes, while the Novice group also included propositions related to Location. This suggested one area of difference. The Expert group did not seem to consider Location an important feature. We speculate that this omission was due to the operational reality that IEDs have been discovered by the Expert group in *many and diverse* locations.

Our comparison revealed other qualitative differences, primarily between the Expert group and the other two groups. In particular, the Expert group included more detail within each theme. While the Novice group only touched on topics within each theme, and the Intermediate group added some details, the Expert group included very specific, and in most cases more, details.

Also, the focus of the Expert group was more nuanced. With their propositions, the Expert group reflected a perspective on themselves that the other groups did not. They considered how Insurgents view them and the environment, how they should prepare for the operational environment, and how the Local Population's perspective is shaped. These nuance differences became our focus of assessment, within the thematic areas. Importantly, these were areas of assessment that coincided with the learning objectives intended to be met by IMT. Thus, the differences between the Expert and other two groups' Concept Maps provided us with content—in the form of propositions—with which to develop our assessment items.

4 Stage 3: Concept Map-based assessment items development

With the assessment areas identified, we developed Concept Map-based assessment items. Our initial items took the form of Multiple Choice Concept Maps (MCCM) items, a novel invention.

4.1 Item development process

The IMT is intended to help develop expert-level thinking with regard to the defeat of IEDs. Thus, we relied on the Experienced Group's Composite Concept Map for content with which to develop the items. In particular, the concepts and propositions in the areas of BLUFOR, Terrain, and Local population included concepts and propositions that were more extensive than the other groups. Thus, these areas were brought into new Concept Maps. Again drawing on the techniques developed by Harter and Moon (2010), the concepts and propositions were arranged to represent Concept Maps that directly expressed the assessment areas—i.e., Concept Maps that clearly expressed the Experienced group composite perspective. Extraneous concepts and propositions were eliminated, and some concepts were restated for clarity, with precaution to not changing their meaning. Synonymous concepts and links were merged or created. Superordinate concepts were created and linked to subordinate concepts. And some concepts and propositions that were included in the Intermediate and/or Novice groups Composite Concept Maps were also eliminated, as these were regarded as simple or obvious. These "assessment" Concept Maps, then, were transformed into the assessment items, described next.

4.2 Multiple Choice Concept Map

The MCCM introduces the multiple-choice testing method into the context of a Concept Map. To our knowledge, this was the first such attempt to blend the strengths of Concept Mapping with the validity of the multiple-choice testing method, for learners of any type. The MCCM is unique in that it requires the test taker to consider an answer to a multiple-choice question *with reference to the rest of the Concept Map*. Importantly, the MCCM provides options of presenting multiple choices at the concept, linking phrase, propositional and Concept Map levels. Essentially, any element within the Concept Map can be transformed into a multiple choice. The selection of elements for conversion into multiple-choice items may be suggested by the content of the Concept Map. False or distracting but relevant items may also be presented, which opens up finer scoring mechanisms. Most importantly, the MCCM is, at once, an assessment and a learning tool. As the test taker proceeds through the Concept Map, s/he is also attempting to understand the presented material in Concept Map form. Unlike the standard multiple-choice testing method, which presents questions serially, outside of any context, and provides little if any reinforcement of learning points, the MCCM requires the test taker to consider the entire learning experience while undergoing assessment.

We created two MCCMs, using CmapTools, which we present below. The two MCCMs dealt with (1) how the BLUFOR may appear to insurgents; and (2) how the local populace may provide indications of insurgent activity. Figure 6 was meant to assess the first area. For each proposition, a choice was provided for one of the concepts. Test takers were to select one of the provided answers (A or B) for each of the numbered items (1-5). For items 1 through 5, strings of propositions were included to provide additional context to consider.

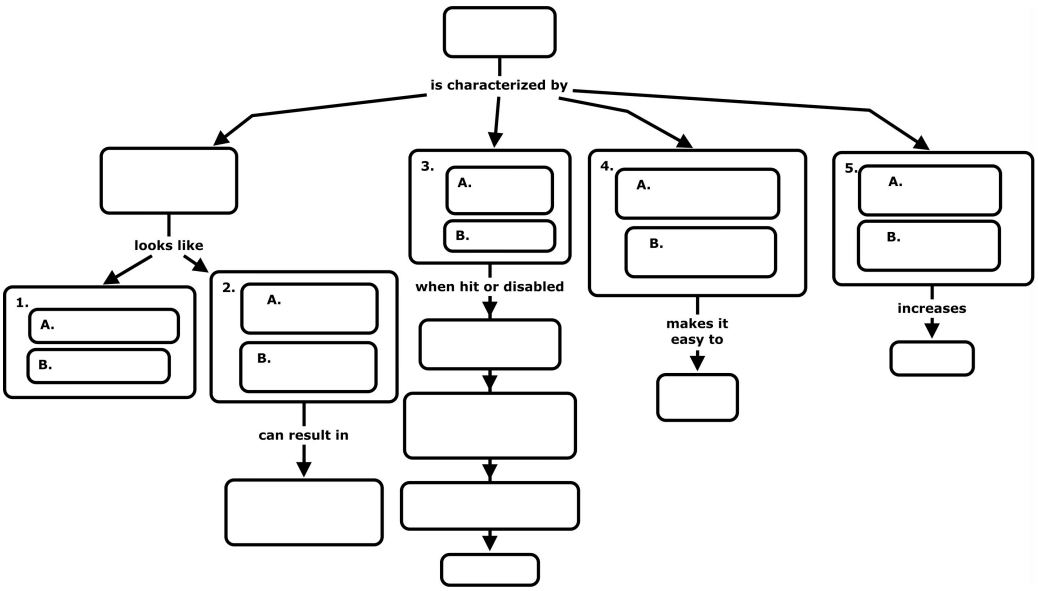

Figure 6. Multiple Choice Concept Map item example #1.

Figure 7 was meant to assess the second area. For each proposition, a choice was provided for one of the concepts. No strings were present. Test takers were to select one of the provided answers (A or B) for each of the numbered items (1-4).

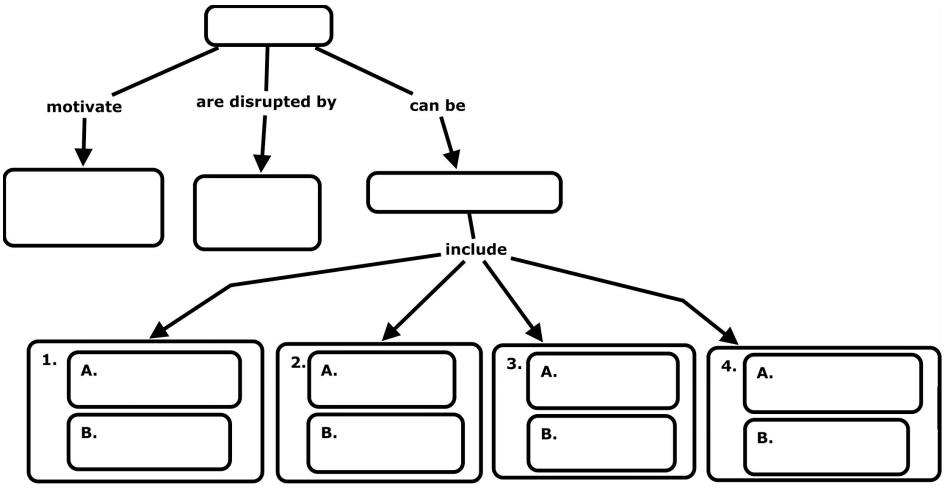

Figure 7. Multiple Choice Concept Map item example #2.

It is important to note that the structure of the MCCMs was suggested by the content of the assessment Concept Maps. For example, in Figure 6, the assessment content was a list of concepts that appeared at different levels of the Concept Map. The concepts suggested binary choices (e.g., on/off, fast/slow). Thus, these became the choices for selection. In Figure 7, however, the content was one to many relationships (i.e., one condition to many enablers). Thus, the structure of the MCCM was the single conditions linked to the multiple.

5 Stage 4: Use of the MCCM items

The MCCMs items were be used in July 2010 during a Test and Evaluation Exercise (TEE). The TEE involved eight military service member Participants, each with varying degrees of operational experience and familiarity with our training intervention. The TEE took place over the course of two days. On the first day, Participants took a Test (i.e., "PreTest"), then trained on the intervention. On the second day, Participants continued training on the intervention, then took the same Test again (i.e., "PostTest").

The MCCM items were included in a battery of 19 items (i.e., the "Pre/PostTest") provided to Participants via a custom-built, interactive assessment tool ("Tool"). Use of the Tool was already underway by the time we introduced the MCCM items; thus, implementation of the items was constrained to the capabilities of the Tool. However, the Tool also afforded capabilities that a not available in a CmapTools implementation—namely, the capability to blend the MCCM items with other types of assessment items and an ability to automatically record and compile answers. The MCCM items were item numbers 16 and 17 in the list, as shown in Figures 8 and 9. All other items were also multiple-choice, requiring selection of one or more answers in response to a stimulus, such as a picture or movie clip. To select answers on the MCCM items, Participants clicked on the correct concept. Figure 8 and 9 show this selection, with the correct concepts outlined in dashed lines, which is how they appeared to the Participants when selected.

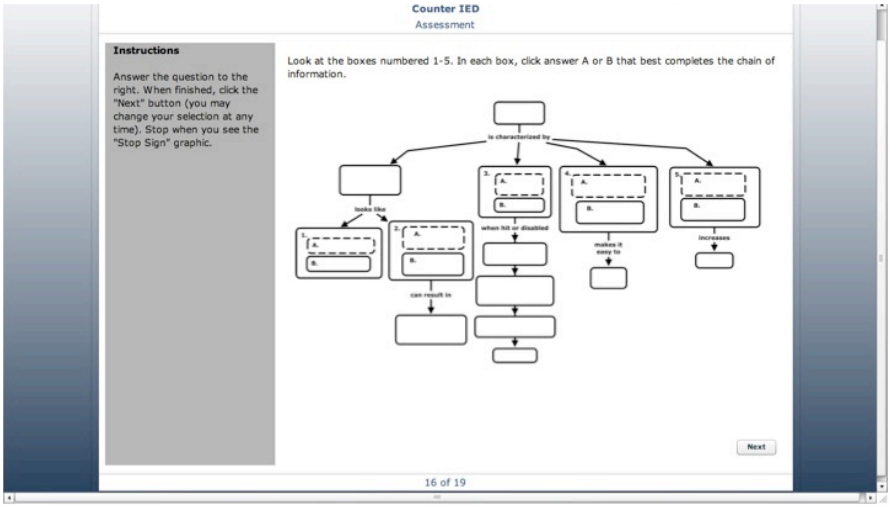

Figure 8. MCCM item example #1, embedded in the Tool.

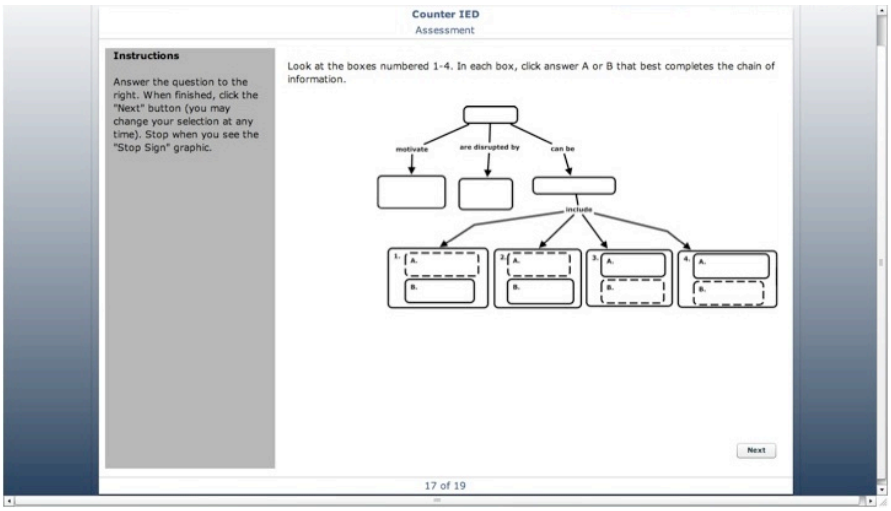

Figure 9. MCCM item example #2, embedded in the Tool.

6 Findings

While our overall effort was concerned with whether our training intervention demonstrated a capacity to change the Participants knowledge about IEDs, for the purposes of this paper we were primarily concerned with whether the MCCM items demonstrated capacity to detect changes in knowledge. We were also concerned with how the Participants responded to the MCCM items.

6.1 Outcomes of the MCCM items

The Participants' responses suggested that the MCCM items detected changes in knowledge. Table 2 presents the outcomes of the items. Correct answers (C) represent the selection of all of the correct concepts. Incorrect answers (I) represent selection of at least on incorrect concept.

MCCM item outcomes, by Participant	Item #16		Item #17	
	PRE	POST	PRE	POST
Participant 1	I	I	C	C
Participant 2	I	I	C	C
Participant 3	C	C	C	C
Participant 4	**I**	**C**	**C**	**C**
Participant 5	**I**	**C**	**I**	**C**
Participant 6	C	C	C	C
Participant 7	C	C	C	C
Participant 8	I	I	C	C

Table 2: MCCM item outcomes, by Participant

In particular, Participants 4 and 5 reflected changes in knowledge. Participant 4 selected one incorrect concept on Item #16 on the PreTest, but selected all correct concepts on the PostTest. Participant 5 selected two incorrect concepts on Item #16, and one incorrect item on Item #17, but selected all correct concepts on the PostTest. Also, for Item #16, Participants showed variance in their incorrect concept selections. That is, they did not all select the same incorrect concepts.

There were clear performance differences for the two MCCM items. For the combined PreTest and PostTest on Item #16, Participants were 50% correct. However, for the combined PreTest and PostTest on Item #17, Participants were 94% correct.

6.2 Observations on the use of the MCCM items

Regarding the Participants' response to the MCCM items, it was noteworthy during the PreTest that several Participants requested in support in answering the items. It was not clear to everyone what the question was requiring of them. One Participant's summed up the problem well in his request for support – he asked "Where is the question?" For some, it was also not clear how to record their answers. This observation was highly instructive, if not surprising. We expected that the MCCM items would present as an unfamiliar format. While we included instructions on how to fill in the answers, it was still not surprising that some Participants did not understand how to read or respond to "the question," particularly in light of the previous 15, standard multiple-choice items.

7 Summary and Discussion

This paper reported on a four-stage approach for Concept Map-based assessment. Concept Mapping was used to identify knowledge differences between performers, and to hone in on areas of assessment of the differences. Concept Map-based assessment items—Multiple Choice Concept Maps—were developed based on the areas of assessment, and used in a demonstration event. The items were suggested to be sensitive to changes in knowledge.

We believe this paper provides a roadmap for future work in the area of Concept Map-based assessment. Given the limited scope, however, it can only be taken as suggestive. We suggest that future work may follow

our four stages, and report on the efficacy of the approach *at each stage*. Future work should also extend the stages. For example, additional research with the MCCMs will be necessary to determine heuristics for matching content to MCCM structure—e.g., one-to-many relationships, use of strings. Further research into the best practices for use of MCCM items is also called for. This research could consider how to best introduce the MCCM items, and also study when and how best to use MCCM items alongside other item types—i.e., do dramatic changes in the item types affect test taking. Also, it is not clear from our effort what the complexity thresholds for MCCM items might be. Clearly, the performance differences on the MCCM items suggested that Item #16 was more challenging than Item #17. This could be due to the difficulty of the content and/or a more complex structure involving strings. Research is necessary to tease these factors apart, and consider how MCCM items might introduce additional complexity with more strings, more concept choices, linking and even proposition choices. Finally, research could also directly compare MCCMs to standard multiple-choice items, on aspects of validity and reliability.

Of great importance in future research could be the development of software tools to directly support the development and use of Concept Map-based assessment items. CmapTools proved highly useful for our first two stages, and was useful in prototyping the MCCMs. However, additional computational capabilities will be necessary to enable creation, scoring, tracking and comparison of Concept Map-based assessment items. We expect to also use and examine other Concept Map-based items types for use in assessing adult learners. In particular, we believe the use of Select And Fill-In (SAFI) Concept Maps is appropriate for adult learners, as Stevens (1997) demonstrated and Schau (2001) confirmed. Our first and second stages will be necessary no matter the item type, as these stages are vital to the identification of areas of assessment. In the next phase of our research program, we will be experimenting with SAFI Concept Maps.

Finally, while we focused this paper on adult learners, in the course of our research we identified no reasons that suggested that our approach would not also be useful for child learners. Indeed, we hope to see the expansion of Concept Map-based assessment approaches in classrooms and other assessment environments where Concept Mapping is an established pedagogical technique. In the United States, Concept Map-based assessment approaches have already been "highly recommended") for inclusion in every National Assessment of Educational Progress Science Assessment at the 8^{th} and 12^{th} grade levels (WestEd and Council of Chief State Officers, 2008, p. 114; WestEd and Council of Chief State Officers, 2007, p. 171). In these contexts, our first and second stages will likely not be necessary, as the areas of assessment will already be identified. No doubt, much could be learned about our third and fourth stages—i.e., by creating and using Concept Map-based assessment items. Hopefully, our contribution will be but one of many in the coming years.

8 Acknowledgements

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References

Harter, A. and Moon, B. (2010). Common Lexicon Initiative: A Concept Mapping Approach to Semi-Automated Definition Integration. In Moon, B., Hoffman, R., Novak, J. and Cañas, A. (eds). *Applied Concept Mapping*. New York: Routledge.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. New York: Cambridge University Press.

Mintzes, J.J., Wandersee, J.H. & Novak, J.D. (2000). *Assessing Science Understanding*. San Diego, CA: Academic Press.

Moon, B., Hoffman, R., Novak, J. & Cañas, A. (in press). *Applied Concept Mapping*. New York: Routledge.

Phillips, J., Moon, B., Yeager, J., & Baxter, H. (2009). Insurgent Mindset Training: A Perspective-Taking Approach to Improvised Explosive Device Defeat Training. Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC). Orlando, FL.

Schau, C., Mattern, N., Zeilik, M., & Teague, K. W. (2001). Select-And-Fill-In Concept Map Scores as a Measure of Students' Connected Understanding of Science. Educational and Psychological Measurement, Vol. 61 No. 1, February 2001 136-158.

Schaal, S., (2008). Concept Mapping In Science Education Assessment: An Approach to Computer-Supported Achievement Tests in an Interdisciplinary Hypermedia Learning Environment. In Proceedings of the Third International CMC.

Stevens, P. A. (1997). Using Concept maps for Assessing Adult Learners in Training Situations. Doctoral Dissertation. University of New Mexico.

WestEd and Council of Chief State Officers. (2008) Science Framework for the 2009 National Assessment of Educational Progress. Contract # ED04CO0148 for the NAGB.

WestEd and Council of Chief State Officers. (2007) Science Assessment and Item Specifications for the 2009 National Assessment of Educational Progress. Contract # ED04CO0148 for the NAGB.