Sero!: A Learning Assessment Platform for Adult Learning Environments

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Abstract. Training and development programs within corporate environments have seen a significant expansion in recent years. Yet there is little research regarding workplace learning assessments. Learning assessments could be used as a tool to gauge employee knowledge in a specific domain area, which can be useful in identifying areas of strengths and weaknesses and indicate where improvement is needed. One way to effectively and efficiently assess workplace learning could be with Concept Maps, a diagramming technique of knowledge representation that has been used to capture the mental models of domain experts. Concept Maps can in turn be used to assess the progress of learners through training and learning curricula. Although the actual set-up and analysis for Concept Maps tend to be rather time consuming and laborious, Sero!, a developing learning assessment platform, holds promise for realizing efficiencies in their use to enable deeper learning assessment. This paper explores the literature about workplace learning assessment, reviews the applicability of Concept Maps for such assessment, summarizes the user-centered design and development of Sero!, and reflects on the boundary conditions for its use.

Keywords: Learning · Training · Assessment · Concept maps · Sero! · User-centered design

1 Introduction

Historically, organizational development, learning and training practitioners have relied on formal learning, instructor-centered methods including training workshops, educational courses, and seminars. More recently however, learning offices have shifted their focus to enabling informal learning and on-the-job training, which is unintentional, pervasive, and ongoing. Examples of informal learning include coaching, mentorship, job-shadowing, and even incidental (trial-by-error) learning [1].

Whether formal or informal, organizations spend billions of dollars annually to train and educate their employees. Yet, apart from programs that require some sort of summative assessment to grant a certification or qualification, almost none of these funds are spent on assessing what the employees have learned. Formal training and learning experiences are typically delivered under a one-size-fits all approach, as the organization typically has little insight into what their learners already know about the topics of interest.

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Informal learning experiences usually rely on the (usually underdeveloped) skills of mentors to ferret out what learners know.

Concept Maps are diagrammatic representations of knowledge that have been used for decades in K-16 learning environments and in applied settings. They were originally developed as an easy method for teachers to quickly ascertain what their students know to help guide the instructional pathway. Volumes of research since have demonstrated that that they can also be used to conduct valid and reliable assessments of learning. In applied settings, they have been used to capture and represent the mental models of experts in a wide variety of domains [2], and have shown promise for assessing adult learning by using the same representations to assess where novices stand along the learning curve [3]. Despite their efficacy and promise, they have proven difficult to efficiently implement for learning assessment. The set-up, distribution, and analysis of Concept Maps is notoriously time consuming, confusing, and laborious, thus preventing their widespread use.

This paper will explore how assessments using Concept Maps might help to enable adult learning in corporate environments. We are developing Sero! – a learning assessment software tool that uses Concept Maps. Goals for Sero! include overcoming the challenges of implementation and supporting adaptive learning by helping teachers and instructional system designers get deeper insight into learner progression, particularly in the advancement of higher order thinking skills. We are taking a design thinking approach in development, and have piloted Sero! in an adult learning environment to capture user experience and feedback.

2 Workplace Learning Assessment

Workplace learning has evolved into a more complex and multifaceted construct that involves formal and informal learning of both, codified and experience-based knowledge. The traditional perception of workplace learning has been flawed "by a logic based on polarities about what is and is not knowledge, and by what counts and does not count as learning" [4]. The primary focus of organizational learning has been based on off-the-job sources of knowledge acquisition including training courses, seminars, and other modes of formal learning [1]. However, the importance of tacit knowledge as being responsible for "90% of the knowledge in any organization [which] is embedded and synthesized in peoples' heads" is also well documented [5].

With this evolution has emerged many challenges to understanding the assessment of learning in workplaces. According to Vaughan and Cameron [6], most workplace learning is not considered or understood to be a form of learning and is therefore unlikely to be assessed. Perceived differences between informal workplace learning and more formal classroom-based learning can lead to confusion as to when actual learning is taking place. "In some cases, assessment is invisible as a topic for attention because it is subsumed within another process" [6]. This point is emphasized in a New Zealand study which revealed that many school teachers "framed some of their assessments as 'teaching' rather than 'assessment', because it took the form of feedback during the process of learning" [6]. The tensions between business and learning imperatives also

provides insight into the challenges for workplace learning assessment. "In workplaces, it is perhaps not surprising that learning comes second to other imperatives such as making products and/or delivering services" [6]. Yet, learning is now a key indicator and driver for productivity [7], and "the demand for ongoing learning has implications for workplace assessment" [6].

Two types of workplace assessment can be delineated. The first is assessment of formal learning in the workplace, often but not always leading to some sort of qualification. Such assessments are almost always summative in nature, occurring at the end of the learning or training experience. The second is the assessment of informal learning that lies at the heart of much workplace learning and is often the source of transfer for tacit knowledge. Informal learning can be assessed either as a summative assessment, or as a formative assessment, which aims to provide feedback to the learner to aid in the learning experience. Increasingly, the playing field is leveling between these two types of assessment, as the "workplace learning literature is increasingly arguing that managing workers' informal learning is important and that this should happen in ways that relate closely to the skills and dispositions needed for knowledge societies" [6]. There is a continuing need for valid, reliable, and feasible approaches to assess both types of learning for summative and formative purposes.

3 Concept Maps

Concept Maps (Cmaps) are a diagrammatic tool for organizing and representing knowledge [8]. The diagrams comprise concepts that describe regularities in a given domain area and lines between them that signify a relation between two concepts, with the relation being specified by a corresponding label or linking phrase. All concepts are represented in a hierarchical fashion with the most general concepts at the top and narrower ones at the bottom. This concept-link-concept format denotes a proposition, "a basic unit of meaning in a concept map and the smallest unit that can be used to judge the validity of the relation (line) drawn between two concepts" [9]. Concept Maps are based on the shared assumption of most cognitive theories in that "concept interrelatedness" is essential to acquired knowledge [9]. Goldsmith, Johnson, and Acton [10] suggest that in order to "be knowledgeable in some area is to understand the interrelationships among the important concepts in that domain". Figure 1 shows a basic Concept Map describing social engineering.

Concept Maps for Assessment. For decades, Cmaps have been used in educational settings in the form of learning aids. However, with growing popularity and the advancement of technology, Cmaps have also proven useful as a knowledge assessment tool. According to Petrovic et al. [11], there are three main aspects of a Concept Map assessment including task demand (such as generate-and-fill-in, select and fill-in, creating a Cmap from scratch, etc.), task constraints (including the presence or absence of a 'concept' or 'relationship' bank), and task content structure (how the structure of the Cmap domain is represented - hierarchical, cyclic, etc.). Their validity, reliability, and potential to yield valuable insight into learning is recognized by the US

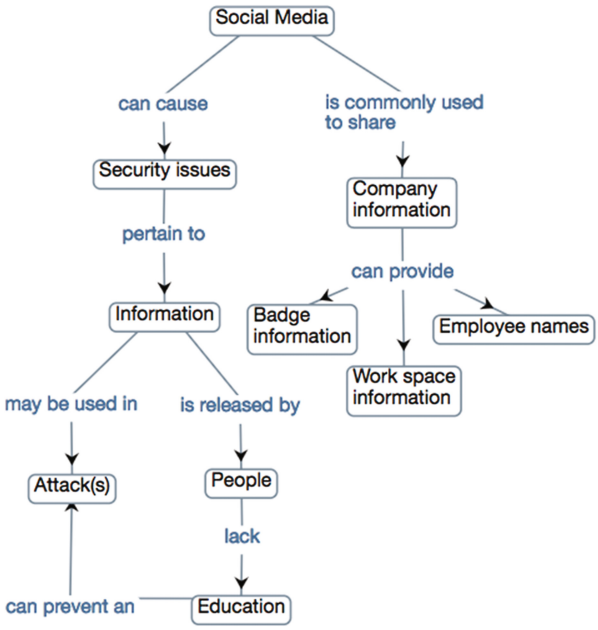

Fig. 1. A Concept Map

Department of Education, which has called for their use in its National Assessment of Educational Progress (NAEP) Science Framework [12].

Concept Maps for Adult Learning Assessment. Although Cmaps have been widely studied and used as both learning and assessment tools in education, there is scant research in the application of these techniques in corporate learning environments [11]. Stevens [13] used incomplete fill-in Cmaps in order to assess adult learning in a Hazardous Waste Operations and Emergency Response training course that is offered to those employees that work with hazardous waste. Results revealed that the "Cmapping method was shown to have higher reliability than the control (multiple-choice-test), and both were positively and moderately correlated in post-test use" [13]. Knollmann-Ritschel and Durning [14] tested a Cmap-based assessment for use in medical military instruction as a team-based learning tool. To assess understanding of specific learning fundamentals, the researchers replaced an individual assessment using multiple-choice questions with Cmaps and combined the assessment with a group assessment and application exercise whereby teams created Cmaps. Results confirmed "the benefit of Cmaps in team based learning…knowledge acquisition, organization of prior and new knowledge, and synthesis of that knowledge benefits across disciplines" [14].

In a demonstration project, Moon et al. [3] used Concept Mapping knowledge elicitation (KE) method which was used to preserve knowledge from three subject matter experts within an organization to mitigate knowledge loss. The resultant Cmaps were converted into assessment tasks delivered through Sero! (described below) and

taken by other members of the organization who were not considered experts in the elicited topics. Because there were no stipulations on the assessment context, some test participants reported actively seeking answers for the assessment via various search strategies – "strongly suggesting the capacity for Sero! assessments to prompt self-learning activities" [3]. The test participants "reported having enjoyed the process, and being challenged by the assessment task," and "indicated that working through the Concept Maps revealed gaps in their mental models of the domains" [3].

Obstacles to Using Concept Maps for Assessment. There are several obstacles to the effective and efficient use of Cmap-based assessments. In theory, Concept Maps have the potential to assess higher order cognitive skills, of the kind Bartlett [15] described:

- interpolation: filling in information that is missing from a logical sequence,
- extrapolation: extending an incomplete argument or statement,
- reinterpretation: rearrangement of information to effect a new interpretation.

In practicality, however, their value is often watered-down because they require extensive preparation and implementation. There are numerous methods by which a Cmap may be evaluated, so "assessors and learner understanding of Cmaps and their purpose can hinder successful implementation. Guidance for selecting which Cmap-based assessment technique(s) to use for which learning purpose is scarce in the literature" [3]. K-12 teachers often resort to simplistic, paper exercises that reveal little about what a student knows or has learned.

The most serious challenge, though, is the time and labor intensive nature involved in the manual set-up, analysis, and transcription of analysis that is required for Cmap-based assessment [3]. Several Concept Map-based software tools have demonstrated value in creating and sharing Cmaps on a large scale, and other prototypes have demonstrated potential for effective Cmap-assessment. None, however, have created a capability for efficiency and scale necessary to implement in learning environments, either for young or adult learners.

4 Sero!

To overcome the aforementioned obstacles, we are developing Sero! a cloud-based platform that enables learning assessment using Concept Maps. Sero! supports two roles: assessor and learner. For assessors, Sero! will enable assessment semi-automated authoring, proctoring, analysis, and feedback to learners. On the learner side, Sero! will distribute assessments and provide an intuitive introduction to and completion of Concept Map-based assessments. Learners will interact with Cmaps in different stages of completion by, for example, manipulating the position of the concepts or linking phrases, or changing the words inside the nodes to create different propositions, making connections between nodes, and identifying errors within the map. Both assessors and learners will have access to analytics that enable adaptive learning.

Sero! addresses the challenges of efficient implementation of Concept Map-based learning assessment. To create the assessment, an assessor needs a Concept Map,

which can be imported from other software if available, or created in Sero! by entering the set of propositions that form the Cmap. Next, assessors identify which concepts, linking phrases, and/or connectors they want to assess. Sero! converts the items into one of five assessment types:

- Multiple Choice (MC),
- Generate and Fill-in (GAFI),
- Select and Fill-in (SAFI),
- Connectors (CONNECT),
- Error Recognition/Revision (ERROR).

The use of multiple item types within a Cmap is an innovation. Prior research has only focused on one item type per Cmap. Learners, then, are presented with an incomplete and/or incorrect Cmap that requires them to interact with each of these item types in order to submit a complete and/or correct Cmap.

We are developing Sero! through extensive, user-centered research as part of the US Department of Defense's Advance Distributed Learning (ADL), Total Learning Architecture (TLA) program (https://www.adlnet.gov/tla/). Our program employs a user-centered design by including several rounds of usability evaluations – i.e., "design checkouts" – with adult learners in the US military.

5 Design Checkout

We have conducted one design checkout with learners in the United States Marine Corps (USMC). The purpose of the design checkout was to:

- Exercise the application under controlled test conditions with representative users,
- Determine design inconsistencies and usability problem areas within the graphical user interface (GUI) and associated back-end functionality, and
- Establish baseline user performance, including time on task, and user-satisfaction levels of the user interface for future usability evaluations.

Sources of error that were of interest included:

- Nature of task confusion – failure to understand the nature of the task,
- Presentation errors – failure to locate and properly act upon desired information in screens, selection errors due to labeling ambiguities, and
- Navigation errors – failure to locate functions, excessive keystrokes to complete a function, failure to follow recommended screen flow.

A design goal for Sero! is to enable learning assessment *without* providing extensive introduction to the Sero! GUI or Concept Maps or Concept Mapping. Thus, the approach for the design checkout was to present Sero! in its then-current form, *with minimal instruction*, to gauge overall intuitiveness.

Participants. A total of nine (9) participants from the domain of training and education standards development were included in the design checkout. All participants executed the learner user role, as the assessor module in Sero! was not available.

Participants were assigned to three groups (A, B, C), with each participant assigned to a group after the prior participant's group.

Basic demographic information was collected from participants. Specifically, they were asked their level of experience with concept mapping and with the domain (training policy). Notably, no participant reported "A lot" of experience with concept mapping. Participants had either "no" or "some" experience.

About one-third of the participants were new to the domain – that is, training and education standards; another third had six months to two years' experience. The remaining participants had more than two years.

Setting. Participants used a laptop computer with a Web browser pointed to the Sero! application, as would be expected in a typical formal learning/training environment.

Tasks. All participants were assigned the same tasks for the first three rounds of tasks – that is, they all were presented with the same maps. In the fourth round, participants were shown one of three maps, depending on their group assignment. The first three rounds presented a relatively simple assessment map, with a limited number of assessment items and types. These maps were based in the same Cmap, which described basic facts about the USMC taken from its Wikipedia page. The three maps used for the fourth round were based in two USMC policy documents describing training and readiness principles and organizational responsibilities that the participants were expected to have close familiarity with. Figure 2 shows one of the maps, as it appeared to the learners in Sero!.

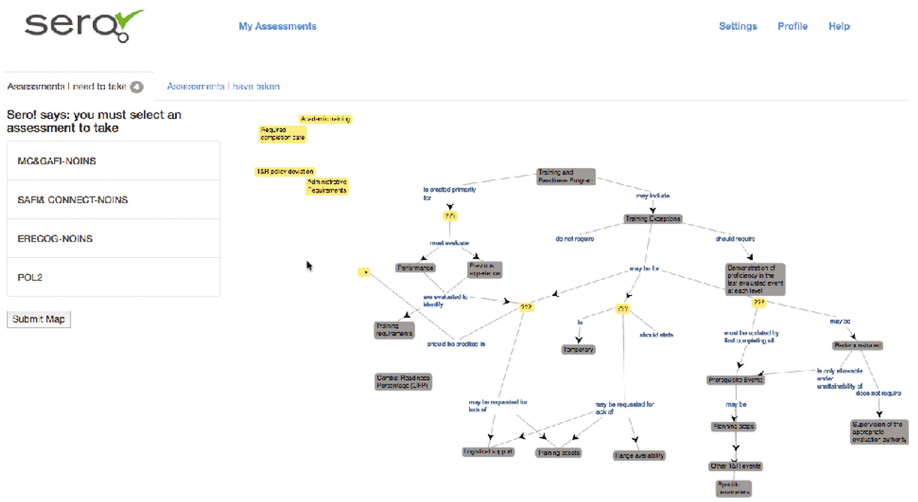

Fig. 2. Sero! assessment map

Usability Concerns. The primary limitation of the design checkout was the number of participants. All findings of a statistical nature should be considered qualified. Despite the limitation, the design checkout results revealed several usability concerns and suggested design changes that would serve as foci for future evaluations.

Primary usability concerns were related to the ability of users to complete the SAFI and ERROR items. In the tested version, SAFI nodes were often not immediately visible, difficult to attach and detach, attachable to CONNECTOR items, and it was not evident how to attach them. ERROR items, while not challenging to answer, were not evident to learners *as items*. The challenge was less about usability and more about the difficulty of prompting the item type. That is, there is a difficulty inherent in prompting a learner to find errors without designating where the errors might be.

Overall, the participant interactions and System Usability Scale [16] scores were considered promising for the following reasons:

- the novelty of the tasks,
- the difficulty of the tasks, including the withholding of any instructions,
- 3 of the 5 techniques were completed at a high rate,
- the completion (number of items completed) to correct (number of items that were completed that were also correct) ratios were favorable,
- the time to complete complex maps is, on average, under 10 min,
- 5 of 7 SUS scores were above 70,
- feasibility scores regarding the use Sero! for learning assessment were favorable.

Specific findings from two participants are also worthy of note. One participant provided a SUS score of 13, and commented that the tasks were "confusing." Excluding this participant's SUS score would bring the overall SUS score to 68 – the average for all systems evaluated using SUS. Interestingly, the same participant was also within the top three performers for complete/correct on the difficult map task, suggesting that achievement of the task was possible despite confusion.

Another participant demonstrated efficient and effective use across all tasks, and was among the most familiar with concept maps. This participant also offered a comment expressing the experience and an interesting perspective regarding preference from the learner and assessor role:

I liked it. I haven't seen anything like this format. I'd like to use it from an education officer perspective. I can see this being really useful for testing someone's knowledge. But as a learner, I'd probably do better on a MC (Multiple Choice).

6 Discussion

Having demonstrated the potential value of Concept Maps for assessment, and shown promise for the usability of Sero!, we can return to the issue of workplace learning assessment to consider when and how our approach may be appropriate and feasible.

Despite the extensive literature regarding the validity and reliability, as well as their inclusion in the NAEP Science Framework, it is not likely that Concept Map-based assessments will be included in summative assessments of formal learning, leading to

professional certifications, anytime soon. Research conducted with adult learners to date has only demonstrated potential, and has not targeted validity or reliability. That said, formal learning experiences that are not intended to lead to certification but include an assessment component may find a Concept Map-based assessment useful. Indeed, developers of such learning or training experiences may find such assessments useful to guide the development of curricula on the front end of development.

For the assessment of informal learning or training, Concept Map-based assessments seem entirely appropriate, particularly where the content of such learning or training targets local/corporate/tacit knowledge. Personalized and adaptive learning experiences in which assessments are embedded in and associated with the designed content, are likely to be a major trend for the foreseeable future [17]. Unfortunately, little guidance on formative assessment in relation to adults can be found [18].

Regardless the application, efficient authoring, taking, and reviewing of a Concept Map-based assessment will be necessary to realize the potential for Concept Maps in adult learning assessment. As Vaughn and Cameron rightly note, assessor "need support…They may have no expertise beyond the level of the course being assessed and may be unfamiliar with assessment requirements beyond a set of tick-box processes" [6]. Through a user-centered design process, we will continue to pursue and explore the kinds of support needed to move beyond such processes with Concept Map-based assessment, delivered by Sero!.

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