CETE Updated Expertise Brief 2019:

Behavioral and Cognitive Strategies

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This expertise brief prepared by CETE staff and updated is a short review of important concepts and areas related to workforce development. Of necessity, it is a brief rather than deep, but a goal is to be as comprehensive as possible. In this brief we present task analysis (behavioral and cognitive) together with a downloadable companion*: a summary of an application of task analysis and a bibliography of theoretical and practical work.*

One way that CETE staff conceptualizes the importance of occupational information is as a form of intellectual property that accrues to the developer and maintainer. Thus, this occupational information is a platform for multiple stakeholders and varied functions from human resources management to career development to interface design to cognitive engineering. According to Jonassen, Tessmer, and Hannum (1989, 1999), task analysis in the design of instruction is a family of methods to specify the "kind of learning that you expect the learners to know how to perform" (p.3). This statement means that designers should begin with terminal behavior(s) in plain sight (hence the importance of task analysis). In fact, Jonassen and colleagues asserted that task analysis is the single most important step of instructional systems design (ISD). This importance is likely only to increase as simulation and model-based approaches to complex performance continue their migration and evolution using technology-based online systems.

Task analysis has a long pedigree. Applications cross industry-business-government sectors and span undergraduate, graduate, and professional levels of education (Carson, Belcher, Hirvela, & Swales, 2001) as well as workforce development. Task analysis in service of workforce development and training is a follow-up, ideally, after an initial occupational-job analysis process and some sort of verification process (survey or focus group). A rough sequence diagram of occupational-job analysis, verification, and task analysis that includes use and revision is provided below. The actual relationship is likely to be more complex, but this linear order lays out the elements.

JOB/OCCUPATION→Global Job-Occupation Analysis→Verification→Task Analysis→Occupational Information Usage→Revision/Re-verification/Re-use

A first step in any task analysis is to obtain the listing of tasks. Consider the system Developing A Curriculum (DACUM), which is a facilitated, committee-based process described by Norton and Moser (2014). It unfolds in application as follows:

- First, a panel of 7-12 expert workers (Subject Matter Experts) is recruited to work with a facilitator over two-three days to produce a DACUM chart containing broad duties, subordinate tasks, and other elements.
- Then, charts are shared with clients (firms, educational institutions, or associations). With client signoff, the chart is designated initial. Or, changes are incorporated and then clients sign-off. Reviews may include the expert workers who participated in the DACUM panel and/or HR staff and this QA step may be expanded.
- Next, CETE staff always recommends verification. A quantitative verification involves surveys (print or online) to "look over the shoulder" of the panel as well as to provide data for high-quality, defensible materials/products. A focus group or committee review, more qualitative in nature, can provide the same sort of overlook but may have different implications. After important tasks are identified and frequency of performance is specified, the quantitative data is tagged in a database of duties and tasks for further work.
- Finally, CETE recommends task analysis to drill-down or elaborate the tasks deemed to be more important through focus group judgment or statistical analysis of ratings data. That recommendation is the heart of this expertise brief and sets the stage.

Below I review behavioral approaches to task analysis, as used by practitioners of DACUM and other procedures, before turning to cognitive task analysis (CTA). An evolutionary step in occupational analysis, rather than a competitor, the importance of CTA for CETE staff is in describing the knowledge and skill for decision-making not only in complex training environments such as simulations and assessment centers but in the world of work. This should be the target of generalization in workforce development. Increasingly, we noticed that task analysis is applied to develop and deploy high-technology learning and training tools such as those discussed by Blumschein, Hung, Jonassen, and Strobel (2009). “Microworlds” for instance are model-based simulators that aim to provide deep knowledge and cognitive skill. In CTA applications, Lesgold and colleagues (Lesgold, Lajoie, Logan, & Eggan, 1990) applied CTA to training technical troubleshooting, medical professions, and military personnel as have Clark and associates (Clark, 2014; Clark & Estes, 1996) and Klein and colleagues (Crandall, Klein, & Hoffman, 2006).

<u>Behavioral Task Analysis</u>

The earliest forms of task analysis were behavioral, with a focus on observables. Task analysis emerged when mass production within factories was becoming a large part of the U.S. economy at the early part of the 20th century and coincided with an emphasis on observable behavior and the environment. Specifically, the time studies popularized by F. W. Taylor and the motion studies pioneered by Frank and Lillian Gilbreth were ways to decompose work for management, training, and improvement. Operationally, a behavioral task analysis conducted by CETE staff is an essential part of a DACUM occupational analysis. Task analysis, generally speaking, is sequenced after the initial committee work and the verification study (see a related CETE Expertise Brief on task verification). One format for conducting the process is to pair two or three SME with a facilitator who can record or more often enter the input into a structured form using a spreadsheet or a database form. The task is first analyzed into steps (2+) and for each step a set of eight elements is applied: 1) performance standards, 2) tools-equipment- supplies-materials, 3) required knowledge-skill, 4) safety concerns, 5) worker behaviors, 6) decisions, 7) cues, and 8) errors. Even with a behavioral approach there are cognitive implications, especially in the elements of decisions, and cues. Jonassen et al. (1999) reviewed multiple task analysis approaches under several categories, specifically identifying the following classes of methods with specific techniques listed in parentheses:

1) job, procedural, and skill based (task description, procedural analysis, job task analysis, & functional job analysis);
2) instructional and guided learning based (learning hierarchy analysis, information processing analysis, & learning contingency analysis),
3) activity-based (activity theory, syntactic analysis, critical incident/critical decision methods, & task knowledge structures),
4) cognitive task analysis (see next section)
5) subject matter/content (conceptual graph analysis, master design chart, matrix analysis, repertory grid technique, & fault tree analysis), and
6) knowledge elicitation (documentation analysis, observation, survey questionnaires, interviews, think-aloud protocols, unstructured group interviews, focus groups, & brainstorming, & structured group interviews / Delphi technique).

Kirwan and Ainsworth (1992), of the Task Analysis Working Group, organized their presentation as follows: <u>Part 1</u> covered Task analysis process—including six human factors issues that included person specification, allocation of function, staffing of job and organization, task-interface design, skills & knowledge acquisition, & performance assurance. The bulk of their book is <u>Part 2</u> which comprises task analysis methods—25 represent larger set of techniques using a standardized format to present each method and facilitate comparisons: Each method is described as task-focused …

1) **data collection**—activity sampling, critical incident technique, observation, questionnaires, structured interviews, verbal protocols;
2) **description**—charting & network techniques, decomposition methods, hierarchical task analysis, link analysis, operational sequence diagrams, timeline analysis;
3) **simulation**—computer modeling and simulation, simulators/mock-ups, table-top analysis, walk-through / talk-through;

4) **behavior assessment**—barrier and work safety analysis, event trees, failure modes and effects analysis, fault trees, hazard and operability analysis, influence diagrams, management oversight risk tree technique;
5) **requirement evaluation**—ergonomics checklists, interface surveys.

Kirwan and Ainsworth (1992) conclude with Part 3 which is 10 task analysis case studies that were consciously selected on based on criteria: 1) span across the six issues, 2) a range of industries, 3) different stages of system life cycle, and 4) diverse range of task analysis techniques.

In summary, behavioral measurement of tasks and environments (Meister, 1985) is an important part of occupational and job analysis for selection, training, and credentialing. A turn toward cognition and constructivism in education and training leads to the large realm of cognitive task analysis.

Cognitive Task Analysis

Since 1950 and based on the human-machine interfaces that emerged during WW II, skilled performance and allocation of functions among persons and machines in core technology production increased in importance consistent with a rise of cognitive psychology and emergence of human factors and cognitive science. More recently the rise of the "knowledge+innovation" economy continues to influence workforce development i9n search of nonroutine problem based learning. These influences combined to create the emphasis on cognitive task analysis with influence from military studies, cognitive Instructional Systems Design (ISD) models, and human factors.

In their introduction to a handbook on CTA, Chipman, Schraagen, and Shalin (2000) defined cognitive task analysis as the extension of traditional task analysis techniques to yield information about the knowledge, thought processes, and goal structures that underlie observable task performance. They presented a prototypic sequence of CTA as extracted from published literature that consisted of the following stages:

- Preliminary phase
- Identifying knowledge representations
- Knowledge elicitation techniques
- Using CTA products

Schraagen, Chipman, and Shute (200) organized the main section of their handbook into three sections, focusing first on individual training, performance assessment, and selection and then on design of human-machine interactions and applications to teamwork situations (e.g., air traffic control, crew resource management. A large number of methods exist for use in CTA. A shorter listing of techniques that are available includes

- PARI (Perception, Action, Result, Interpretation);
- GOMS (Goals, Operators, Methods, Selection Rules);
- CDM (Critical Decision / Incident Method); and
- ACTA (Applied Cognitive Task Analysis)

Rather than adversarial views, as noted above we view CTA as an evolution of task analysis that adds the internal representations and linkages to the overt and environmental elements captured by behavioral task analysis. One clear focus of cognitive task analysis is understanding knowledge and cognitive skills, perhaps those involved in troubleshooting or diagnostic work (from automobiles to computers to medical or veterinary cases) or military decision-making (battle space leadership ranging from squads up to battalion, regiment, or division levels) to business or government leadership.

Shortly thereafter, the Crandall et al. (2006) book titled *Working minds* provides, in our view, an excellent guide for practitioners interested in cognitive task analysis – CTA as it is called. Crandall et al. organized their presentation into sections following an introduction and an overview of methods; the sections are

- Tools for understanding cognition in context (chapters 3-7)
- Finding cognition (chapters 8-10)
- Putting CTA findings to use (chapters 11-15)

In Crandall et al. (2006), the structure of each case, where possible, includes problem-reason, background, objectives, methods & modifications, resourcing, results of analysis with impact on design, recommendations-conclusions, lessons learned, cost-effectiveness, and impact in terms of perceived benefits.

SUMMARY-CONCLUSIONS

At CETE, we believe strongly that task analysis is fundamental in a range of applications of our workforce development projects whether focused on curriculum/instruction or testing. A plethora of techniques exist, and a profitable merger of behavioral and cognitive approaches may be the integrated task analysis model or ITAM (Ryder & Redding, 1993). There is not enough comparative research with high-quality outcomes. Clark (2014) made this point in his focused review of CTA across healthcare education and roles (e.g., nurses, physicians, dental hygienists, surgery residents). Clark further limited his coverage to evidence-based and peer-reviewed methods, which we believe is appropriate given a lack of comparative research. His conclusion was that there are six methods with stronger support for application. Table 43.2 in Clark et al. (2008), adapted from Wei and Salvendy (2004), provides guidance for selecting CTA methods across 11 situations that occupational analysts might encounter.

The Applied CTA model (ACTA) proposed by Militello and Hutton (1998) and the accessible *Working minds* (Crandall, Klein, & Hoffman, 2006) provide excellent coverage of specific techniques; the latter provides assistance in the selection of a specific tool. There is a growing realization that comparative studies are required to sort and sift among PARI, GOMS, and related approaches, but meta-analysis suggests that training developed through certain types of CTA is more effective than traditional task analysis (R. Lee, 2004; Tofel-Grehl & Feldon, 2013). Still, there is room for improvement in CTA, as indicated in summary sections of published research (Clark, 2014; Crandall et al., 2006). Therefore it is important to track this area of practice and theory in order to stay current. One example of a crucial application would involve applications to “serious games” used in training and monitoring experts (harbor master, fire battalion chief, or paramedics).

Lastly, there is a need to ensure quality and efficiency in CTA methods, so that cost and time concerns do not drive away users who could profit from the application of the techniques. One way that this can be handled is through comparison and implementation research, as noted above, but an intriguing advance (possibly underway) would be a CTA on doing CTA. Apply the process to the process reflexively, in other words, which we have seen in a DACUM chart developed for the DACUM Facilitator role and periodically revised (Norton & Moser, 2014).

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APPLICATION of Cognitive Task Analysis to Dental Hygiene Profession

An application of CTA reported by Cameron et al. (2000) may be instructive (cf. MIslevy, Steinberg, Breyer, Almond, & Johnson, 1999; Steinberg & Gitomer, 1993). Paraphrasing from the author's article abstract, simulation-based examinations can be judged on their capability to call for and interpret observable evidence about targeted knowledge, strategies, and skills in a manner that is valid and defensible. In this case, a business venture called Dental Interactive Simulations Corporation or DISC wanted to develop a scoring algorithm for a simulation-based dental hygiene initial licensure examination. The application of CTA is based on this intended purpose.

The first phase in developing scoring systems is the completion of a CTA of the dental hygiene domain. This is be relevant for instructional monitoring of progress (formative) as well as credentialing (summative, high stakes). One of the CTA steps reported was creation of a specifications map to provide a framework of the tasks and knowledge critical in dental hygiene work in a variety of settings. Using this specifications map, broad classes of behaviors that would tend to distinguish along the dental hygiene expert-novice continuum were identified. Also, nine (9) paper-based cases were designed with the expectation that solutions of the cases would vary by expert, competent, and novice dental hygienists (i.e., along an expertise continuum). Interviews were conducted with 31 dental hygiene students and practitioners to capture solutions to the paper-based cases. Transcripts of the interviews were analyzed to identify *performance features* that differentiate interviewees on the basis of expertise. These features were more detailed and empirically grounded than the originating broad classes and better serve to ground the design of a scoring system.

The results of the CTA provide critical information for defining the necessary elements of a simulation-based dental hygiene examination applicable for education-training and credentialing (certification, licensing), or for employee selection, training, and performance management. The performance features were presented in 9 major categories which represent a skeleton of the practice domain for sampling items and / or performance tasks.

1) gathering and using information
2) formulating problems-investigating hypotheses
3) communication and language
4) scripting behavior
5) ethics
6) patient assessment
7) treatment planning
8) treatment
9) evaluation