COGNITIVE ERGONOMICS AND KNOWLEDGE MANAGEMENT: A NEW MODEL OF ADDRESSING AVIATION ISSUES

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The field of cognitive/knowledge engineering (CE/KE) has expanded to encompass a subset called knowledge management (KM). The main difference between KM and KE is that the knowledge manager establishes the direction the process should take, whereas the knowledge engineer develops the means to accomplish that direction. Cognitive Ergonomics, also a discipline within CE/KE, deals with decision-making, skilled performance(s) and training with a focus on the fit between human cognitive abilities/limitations and selected task(s)... all areas vital to aviation. This paper will briefly show the components and processes of a new model for decision-making using all these disciplines and Pareto analysis in a blended Delphi, beginning with a small group delphi (SGDP) addning in estimate-talk-estimate (ETE) techniques and ending in a real time Delphi (RTD). This paper will outline how this new paradigm can be used on a current aviation issue; showing a blueprint/framework for the actual process of the paradigm.

In 2016, one finds an expansion in the the field called cognitive/knowledge engineering (CE/KE) has occured and is still in progress. KE was defined in 1983 by Edward Feigenbaum and Pamela McCorduck as follows: "KE is an engineering discipline that involves integrating knowledge into computer systems in order to solve complex problems normally requiring a high level of human expertise." There is a new emphasis on a related discipline: knowledge management (KM). Knowledge management (KM) has been defined as "...the practice of selectively applying knowledge from previous experiences of decision making activities with the express purpose of improving the organization's effectiveness." (Jannex, 2014). The main difference between KM and KE seems to be that the (knowledge) manager establishes the direction the process should take, where the (knowledge) engineer develops the means to accomplish that direction.

There is also a somewhat new emphasis in the KE/KM fields on ontology, a term that comes from philosophy. A KE/KM ontology compartmentalizes the variables needed for some set of computations and establishes the relationships between them; thus, an ontology is used to limit complexity and to organize and structure information. It is then a practical application of philosophical ontology, with a taxonomy. Applications are AI, information science and technology, decision-making and much more. The author is here attempting to show how a Small Group Delphi Paradigm (SGDP)/Estimate-Talk-Estimate (ETE) amalgam with a modified Real Time Delphi (RTD) could be used on some specific problems, as well as adding in the use of a mini-Pareto as a start point. All done in the hopes that such efforts might be seen and be of some interest, even be of some help in decision-making. [Note; the author has authored/co-authored some 10 articles and and 2 book chapters on decion-making in the unforgiving aeronatical environment; space truly precludes a listing here and especially in the **referecences** section]. The article will present a "how to" for using this modification on a specific aviation problem.

The Delphi and its Characteristics

The Delphi method was developed by Project RAND during the 1950-1960s. Delphi techniques, a subset of CE/KE, have become common methodologies for eliciting analyses, expert opinions and evaluations on a variety of topics. Meister (1985) noted “The (Delphi) methodology is by no means fixed…[it] is still evolving and being researched." This is as true now as it was when Meister stated it. In point of fact, with the leaps in communication methods and related computer technology, this is even more true today. The rationale for this statement is actually two-fold. The first being that in the last 10 to 15 years, there has been quantum leaps in computer memory/power as well as communication technology that uses desk-top computer, even iphone technology. These leaps and advances seem now to occur almost daily. Concomitantly, Delphi techniques have recently begun to look at and attempt to take full advantage of these advances.

The following key characteristics of the Delphi method help the participants focus on the issues at hand and, what separates Delphi from other methodologies:

1. Anonymity of the participants.
2. Structuring of information flow.
3. Regular feedback.
4. Role of the facilitator.

The person coordinating the Delphi method can be known as a facilitator or leader, and facilitates the responses of their panel of subject matter experts (SMEs).

What has been presented above is the standard description and rationale for the Delphi process..

From Small Group Delphi Paradigm to Knowledge Management

This article was over 30 years in the making. It begins with a specific problem and task: to develop for the U.S. Army Aviation Command an aviator candidate selection test, later termed Multitrack, that also showed which of the current rotorcraft (the U.S. Army uses this term, not helicopter as do other U.S. military services.) would be the optimum operational aircraft placement for the candidate upon completion of initial training. At this point, the author, who was experienced in team training and group function/dynamics, decided to develop a modification to Delphi processes wherein the abilities approach of Fleishmann was used with face-to-face, small groups. Highly experienced and with high performance evaluations Army aviators were brought in from all Army posts world-wide, functioned as subject matter experts (SME's). In the ability requirements approach of *Taxonomies of Human Performance,* Fleischmann and Quaintance (1984, revised 2000): the ability requirements theory/approach is away of describing and classifying human tasks. In this approach, tasks are described, contrasted, and compared to the abilities required of the individual performing a specific task. Once a set of tasks is identified, a human performance taxonomy can be developed from it. Taxonomy, as used here, denotes a system that classifies and describes human tasks according to a particular focus, such as the abilities seen as essential to a specific task. Thus, as it was termed, the SGDP (Lofaro, 1992a), took the Delphi process in another direction by modifying it via merger with elements of group dynamics in order to have interactive (face-to-face) Delphi workshops

The SGDP then accomplished what had never been done before. It delivered an operational, computerized set of tests with scoring algorithms that not only selected the optimal aviator candidates for initial pilot traing but also showed which of the four then-existing rotorcraft types these candidates should be placed for transition training in upon completion of initial training.... Tthe U.S. Army Aviation Command not only used Multitrack but, there was a very high predictive validity as to both selection and placement. It now seems that the SGDP was a KM effort.

While the definition of measures of KM success did not exist in 1986 (and not even throughout the ensuing use of the SGDP into 2003), nor did the Jennex and Olfman KM Success Model (Jennex, 2013), it would seem, that in part, these measures were somewhat met by the Mutitrack test/scoring algorithms resulting from the SGDP. Examples: A KM Success Model measure of KM success is system quality. In the SGDP the SME's created/produced knowledge that was stored, able to be retrieved and was applied. That knowledge probably could not have been otherwise captured as the SME's may not have been available later, the need for their specific expertise had not, nor would be asked for again. But Army Aviation needed it exactly then. Knowledge quality was achieved as the knowledge was shown to be useful as to correctness and inclusion. The service quality was seen in the performance impact of the using (making operational) Multitrack and subsequent U.S. Army Aviation Command satisfaction.

The Small Group Delphi Paradigm: Past Uses

From 1987 through 2003, the SGDP was adapted and used in a broad spectrum of tasks, from ATCS selection (Gibb and Lofaro, 1993); to managerial core competencies(Lofaro,1998); to flightcrew performance evaluation (Lofaro, and Smith, K.M., 2007); to useability testing (Lofaro & Maliko-Abraham, 2002; Maliko-Abraham & Lofaro, 2001, 2003); to work on a mission performance model for flight crew resource management integration and evaluation. (Lofaro, 1992b); to selection and evaluation of aircarriery baggage screeners (Lofaro, Gibb and Garland, 1994; Gibb and Lofaro, 1994). It must be noted that the successful use of SGDP techniques by others indicate that the techiques are not dependent on who administers them; rather, they not only are effective across venues but also with different personnel directing/facilitating the SGDP workshops. These successful adaptations, modifications, implementions, across many venues, showed that the SGDP is both transferable and generalizable and possesses external validity. The SGDP can be used for any project that requires that a set of SMEs be used to identify, evaluate and criticality rate tasks (an enhanced task analysis); to identify core needs/skills; to recommend modifications to equipment, procedures and training. Finally, the SGDP can be used to sharpen, modify and revise existing methodologies.

The Small Group Delphi Paradigm: 2016 Technological Modifications

Some twenty-five years after the SGDP was devised, used and appeared in multiple publications, it has been re-discovered, as it were, and is now recognized as an acceptable CE/KE method. The use of face-to-face groups in a Delphi is now a fact and is termed Estimate-Talk-Estimate (ETE). New communication capabilities and technologies seem to have driven the development of what are generically referred to as a mini-Delphi or ETE, with many variants. There is also the Real Time Delphi (RTD) that maintains anonymity but uses computer linking for a high level of instantaneity (Gordon, T. J., & Pease, A., 2006). While the SGDP structure and processes are still relevant, they can be and are in real need of some level of integration with ETE/RTD techniques and current advances in computer and communication abilities and techniques. The author's belief is that the result of an integration would be a revised Delphi that will produce the same level, if not a higher level, of accurate information, decision-making guidance and products in the aviation arena, or many other venues. In modifying the SGDP for use with today's technology and advances in KE/KM, any problems to be investigated would require, as a first step, the building a model of a knowledge domain, defining the terms inside that domain and the relationships among them...developing an ontology. We will return to this later.

A Model Of A Blended SGDP/ETE/RTD...And Beyond

The core SGDP structures to be maintained are: the careful selection of a limited number of SMEs (however, there can be many small(er) SME groups functioning at one time), the use of an extensive read-ahead package for the SMEs, the use of some facilitation and group dynamics instruction, combined with some type face-to-face sessions. One example of a difference in an ETE or RTD (a computer-based Delphi with anonymity) versus either a tradtional or SGDP Delphi: the iteration structure used in the tradtional or SGDP Delphi, which is divided into three or more discrete rounds, can be replaced by a process of continuous (roundless) interaction, enabling SMEs to change their evaluations at any time. A new ETE/RTD/SGDP model would be computer-based. The reader is referred to the work of Turoff and Hiltz (1996) on computer-based Delphis.

Integration of the SGDP with a ETE/RTD (*sans* anonymity) approach can be achieved thusly: all participants can be logged on simultaneously, each participant can briefly state their name and credentials, the group dynamics instruction can be done by the facititator to all simultaneously (aside: it would seem that a linked network of all SMEs is possible and even *de rigueur)*. The SGDP face-to-face group meeings would now be done on-line. This will allow for instanteous feedback by any SME during a session, as well as discussions). The iteration structure used in SGDP, which is divided into as many discrete rounds as needed for consensus, can be replaced by a process of continuous (roundless) on-line interaction, enabling SMEs to change their evaluations at any time and give a rationale with ensuing

discussion in real-time. Finally, the statistical group(s) response(s) can be updated in real-time and shown whenever a SME, or a group, provides a new evaluation. It is clear that "face-to-face" discussion will be virtual. This is, to the author, a real and significant loss. But, the speed, multiple iterations, real-time, access to a large number of SMEs and other aspects to be gained cannot be ignored. Another possible modification is a multi-tiered SGDP/ETE/RTD where the use of two or more groups working differnt problems can be convened and given objectives based on their expertise. As these groups come to consensus on their objectives, these new data can be integrated, built into a new re-ahead package and made available to a new set or participants with new or prior SME's.
A second modification would be use of only specific elements of a Pareto Analyis as the first step after the group dynamics instruction. This is because such a step would identify problems, then, sharpen (focus in on the ones that are amenable to resolution) while, at the same time, providing an ordering of which should be worked on via criticality ratings. The elements of the Pareto Analysis would be the first three steps in such an analytic technique. Step 1: Identify and list problems to be examined. Or, if and only if one problem/issue exists, a break-out of the sub-problems could be done. Step 2: identify causal factors inherent in each problem. Step 3: Score (in this case, criticality rate) the problems, resulting is a somewhat rough ontology. The Pareto, done in the context of a SGDP/ETE/RTD could also allow for many possible solutions to be evaluated by many types of SMEs with differing areas of expertise but in areas germane to the problem. This would result in a winnowing down of courses of action to those that were realiostic and possible of success. The advantages of using a Pareto, core SGDP structure and ETE/RTD (all computer/Internet driven) are that they are all content-area neutral and, in a real sense, generic in application.

A Specific Aviation Issue/Problem

This paper will only deal with one current commercial aviation issue (as the author has 26 years of experience in aviation; United States Air Force, Army Aviation Command, and the Federal Aviation Administration (FAA), that choice seemed simple). There is a significant amount of controversery over upset training; training pilots to recovery the airplane from unusual (unstable; dangerous; rarely encountered) attitudes thereby not having potentially fatal accidents. The Air France Flight 447 accident, for example: A series of errors by pilots and a failure to react effectively led to the crash of Flight 447. The plane went into a sustained stall, signaled by a warning message and strong buffeting of the aircraft. Despite these persistent symptoms, the crew never understood they were in a stall situation and, therefore, never undertook correct recovery maneuvers. In other words, a high altitude, high speed stall was a situation the crew was unable to recognize much less had ever trained for. The Colgan Air crash outside of Buffalo, NY is another fatal accident where the U.S. National Transportation Safety Board (NTSB) determined that the probable cause of this accident was the Captain's inappropriate response to the activation of the stick "shaker" (the airplane's main control device actually shakes/vibrates in the pilot's hand if the plane is in danger of stalling/spinning) which led to an aerodynamic stall from which the airplane did not recover. To further cloud the issue, the American Airlines upset prevention and recovery training (UPRT) ground school with flight simulator (FS) training, called advance aircraft manuevering program (AAMP), was seen by the NTSB as possibly a contributing factor in the American Airlines flight 587 crash in 2001 (Croft, John. 2014a).
The FAA, while not yet issuing an Advisory Circular (AC) or a Federal Aviation Regulation (FAR) has issued a document called Airline Upset Recovery Training Aid, version 2. The current issues seem to be use of a full motion FS, that will be part of an expected FAA pilot training rule by 2018 (Croft, John. 2014b), versus in-aircraft training (or some combination) and swept wing jet aircraft specialized training. It is believed that a modified SGDP/ETE/RTD, using senior pilots as SME's can point a way to types/procedures and applicability for upset training.

This SGDP/ECE/RTD would proceed thusly: A multi-tiered effort, beginning with the Pareto described above to identify 2 or 3 issues that most need solutions (a quasi-ontology) from the issues cited above: use of a full motion FS and/or in-aircraft training and/or swept wing jet aircraft specialized training.

Next, as always , multi-tiered, identify the sub-issues involved. Here, as with the remainder of the SGDP/ETE/RTD, the data needed for all tiers/sub-tiers would come come from SGDP/ETE/RTD's consisting of 5 to 9 (senior) pilots from as many aircarriers as possible. Possibly, each interested carrier initially could do such efforts. In this way, each carrier would have results based on their mission and objectives for possible upset recovery training. Since the multiple sub-tiers would only be dealing, at first, with one specific arena, the results could be used grist for another round(s) where consensus, via criticality ratings and discussion, is worked on. This multi-tiered approach can be used for all the issues listed above-simultaneously or sequentially. In a second, or as an extension of the first SGDP/ETE/RTD, the SME pilots can identify and sort these upset recovery maneuvers into taxonomies for those which are primary and necessary for what can be called an air carrier's "basic training" for aircrew, then for transition training and for recurrent training. Again, in a tiered series of SGDP/ETE/RTDs.
The use of a FS (What type? What recovery techniques can be taught in FS and which require in-plane training? And for which planes?). What are the performance standards for each manuever? Answers to these all would be results from such an effort. It may be possible that the large amounts of data being developed ("soft data" as they are the results of opinions and/or criticality ratings) could be handled by data & knowledge engineering (DKE) methods. Finally, these SGDP/ETE/RTD techiques can be used for many other existing problems; in aviation, flight crew rest/fatigue immediately comes to mind.

FUTURE DIRECTIONS

It must be strongly noted that the article is not a report on the results of prior experimentation, rather it is an attempt to meld a modified Delpi procedure with today's KE efforts and today's technology. It is an attempt to indicate the structure of this new, modified Delpi. More importantly, it is also a call for research efforts to try the new procedures and validate (or not) them. Would that the author were still in prior positions as a government agency researcher/manager; the author could have attempted these efforts. This is not the case today. This article provides a rough template for future research.

References

Croft, John. (2014a). Unambigous Upset. Aviation Week & Space Technology, Vol.176, No.20, 52.

Croft, John. (2014b). Unambigous Upset. Aviation Week & Space Technology, Vol.176, No.20, 53.

Feigenbaum, Edward A, McCorduck, Pamela (1983). The Fifth Generation (1st ed.). Reading, MA: Addison-Wesley.

Fleishman, Edwin A. and Quaintance, Marilyn K (reissued 2000). Taxonomies of human performance: The description of human tasks. Potomac, Maryland. Management Research Institute, Inc.

Gibb, G.D., Lofaro, R.J. et al. (1993). Computer-based Assessment of Air Traffic Controller Abilities: Experimental Selection Tasks in *Proceedings of 1993 Aerospace Medical Association Annual Symposium*. Alexandria, VA..

Gibb, G.M., Lofaro, R.J. (1994). Airport Security Screener and Checkpoint Security Supervisor Training Workshop. DOT/FAA/CT-94/109. Springfield, VA: National Technical Information Service.

Gordon, T. J., & Pease, A. (2006). RT Delphi: An Efficient, "Round-less," Almost Real Time Delphi Method in *Journal of Technological Forecasting and Social Change,73(4),* Amsterdam , NX., Elsevier B.V.

Jennex, Murray (2013). Knowledge Management Success in an Engineering Firm in *IEEE Engineering Management Reviews, volume 2, issue 2.* Victoria, Australia. IEEE Technology and Engineering Management Society.

Maliko-Abraham, Helene and Lofaro, R.J.(2003). Usability Testing: Lessons Learned and Methodology in *Proceedings* of the 2003 International Military Testing Association (IMTA) Conference.

Maliko-Abraham, Helene and Lofaro, R.J.(2001b). Air Traffic Delays: New ATC Equipment Coupled With New ATC Candidate Selection Methods May Be One Answer in *Proceedings* of the 2001 National Air Traffic Controllers Association (NATCA).

Lofaro, R.J., Gibb, G.M., and Garland, D.(1994). A Protocol for Selecting Airline Passenger Baggage Screeners. DOT/FAA/CT-94/110. Springfield, VA: National Technical Information Service.

Lofaro, R.J. (1992a). A Small Group Delphi Paradigm in *The Human Factors Society Bulletin, 35 (2),* 1-4.

Lofaro, R.J. (1992b). Workshop on Integrated Crew Resource Management (CRM). DOT/FAA/RD-95/5. Springfield, VA: National Technical Information Service.

Lofaro, R.J., (1998). Identifying and Developing Managerial and Technical Competencies: Differing Methods and Differing Results in *Proceedings of 42nd annual Human Factors and Ergonomics Society.*Santa Monica, CA.

Lofaro, R.J. and Maliko-Abraham, H. (2002). Techniques for Developing High Predictive Validity Selection and Screening Test Batteries in *Proceedings* of the 2002 World Aviation Congress; Phoenix, AZ.

Meister, David (1985). *Behavioral Analysis and Measuremen.* New York, NY. Wiley Press.

Turoff, Murray; Hiltz, Roxanne Starr (1996). Computer-based Delphi processes in Michael Adler, Erio Ziglio (eds.). *Gazing Into the Oracle: The Delphi Method and Its Application to Social Policy and Public Health,* 56-88. London, England: Jessica Kingsley Publishers