COLLABORATIVE DEVELOPMENT OF EXPERTISE: AN EFFECTIVE LOW-TECH APPROACH TO ON-THE-JOB TRAINING

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ABSTRACT

The Collaborative Development of Expertise (CDE) is an effective, low-cost training methodology for conducting one-on-one training and team training. Preliminary validation results reveal CDE s effectiveness in promoting (1) greater trainee participation during post-exercise debriefs, (2) better match of trainee-instructor prioritizations during a training exercise, and (3) higher trainee scenario performance as compared to a control group. Furthermore, instructors using CDE (1) use a greater breadth of instructional strategies, (2) are more flexible in the strategies used, and (3) are better able to match the right instructional strategies to the type of performance issue. This paper describes the components of CDE, the steps involved, and discusses the learning theory behind these components. CDE provides the instructor and trainee with a step-by-step training methodology, as well as a toolbox of instructional approaches for unpacking the expertise of the instructor. The process begins with the instructor fostering a more collaborative training environment. Next, CDE uses Cognitive Task Analysis to delineate the types of challenges associated with a job. These challenges provide a framework for the instructor and trainee to diagnose training deficiencies together. Instructors further categorize observed performance obstacles as either a knowing, thinking, or doing-related problem. These categories help the instructor to identify whether the problem involves a lack of declarative knowledge, difficulty in decision-making, or whether the trainee is having trouble with the procedures associated with a task. Categorizing problems in this manner serves to further facilitate diagnosis, and provides a basis for choosing an appropriate instructional approach from the many provided to the instructor by CDE. Finally, CDE empowers trainees to use knowledge elicitation approaches to help unpack the instructor s expertise, as ownership of the training belongs to both the instructor and trainee alike when the using the CDE process. Future work in evaluating and refining CDE is proposed.

ABOUT THE AUTHORS

Dr. Daniel McDonald has been a Research Psychologist at the Naval Air Warfare Center Training System Division since 1999, and was formerly a Research Fellow at the Army Research Institute from 1993-1999. He received his Ph.D. in Applied Experimental and Human Factors Psychology in from the University of Central Florida in 2001, and obtained an M.S. in Ergonomics in 2000. He has conducted research in the areas of decision-making, on-the-job-training, training and human performance in virtual environments. He has won several awards for his work as a researcher and has published over 30 technical reports, book chapters, journal articles, and conference papers.

Dr. Kimberly Smith-Jentsch holds a Ph.D. in Industrial/Organizational psychology and has been with the Naval Air Warfare Center Training Systems Division since 1995. She has designed and managed several large-scale field data collection efforts on the topics of mentoring, intra-team feedback, leadership, performance measurement, team competencies and continuous learning. She has also acquired extensive applied experience developing training materials that have transitioned to the fleet such as a computer-based training tool, an instructor training workshop, debriefing guides, and handbooks on topics such as performance measurement, leadership, debriefing strategies, and teamwork competencies. Additionally, Dr. Jentsch has conducted training workshops attended by over 1500 Navy instructors at shore-based facilities and underway as part of regularly scheduled shipboard training. Dr. Jentsch has won many awards for her outstanding research and has published over 50 journal articles, book chapters, technical reports or conference proceeding papers in her areas of research.

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INTRODUCTION

The military and other organizations rely heavily upon more experienced personnel training those who are less experienced on the job. In fact, On-the-Job Training (OJT) has become the most widely used training modality in the American workplace. Approximately 180 billion dollars is spent each year on this type of training (Tannenbaum & Yukl, 1992). The Navy is currently investing dollars in new embedded and deployable training devices, which will be used while on the job aboard ships, submarines, and during flight. The Chief of Naval Operation (CNO), through Taskforce EXCEL, and Commander Fleet Forces Command (CFFC), are also currently evaluating and implementing mission essential training approaches, which will include OJT as an integral part of the requirements. Additionally, research and development endeavors are focusing on OJT as a means for training. The Office of Naval Research is currently funding OJT research and development, with the objective of transitioning new OJT methods to the fleet. These methods, while including automated training systems and high tech solutions, also include very effective low-cost approaches.

Currently, there are few formal mechanisms in place to facilitate the transfer of skills and knowledge from experts to the more inexperienced on the job. One such approach being transitioned to the fleet is Team Dimensional Training (TDT). TDT is a theoretically based, empirically validated training solution for training teamwork that is attractive to the fleet because of its demonstrated effectiveness and the potential return on investment compared to the price of its implementation. The Collaborative Development of Expertise (CDE) is another such low-cost approach. CDE, developed by Klein Associates and the Naval Air Warfare Center Training Systems Division (NAWCTSD), provides a framework for helping instructors and trainees of complex tasks to unpack the expert s knowledge for training benefit.

CDE — An Overview

CDE combines training research and learning theories into a comprehensive methodology that facilitates better transfer of expert knowledge and skills between experts and novices. CDE focuses on improving the quality of the instructor s instruction, and encouraging the learner to take an integral and active role in his or her improvement during training. The learner and the instructor are viewed as partners who collaborate during the training process to maximize opportunities for the transfer of expertise, so that advanced skill development can occur faster and more effectively.

Preliminary validation results for CDE revealed that it was more effective for increasing trainee participation during post-exercise debriefs than the control condition. More participation by trainees is believed to increase their ownership over their own training and, through open communication, provide instructors with better insight into the difficulties that a trainee may be experiencing. Increased similarity between trainee and instructor prioritization of occurring events during a training exercise has also been found using CDE. It appears that CDE promotes a more shared understanding as to what is most important during task performance. This shared understanding suggests that the trainee is beginning to acquire their instructor s expertise. CDE also produces improved trainee exercise performance over traditional debriefing approaches. Furthermore, validation results have shown that instructors using CDE employ a greater breadth of instructional strategies, are more flexible in the strategies used, and are better able to match the appropriate instructional strategy to a particular performance issue (see Stanard, Pliske, Crandall,

Zsambok, Green, McDonald, & Jentsch, 2001). It is believed that the instructor s greater repertoire, flexibility in instructional strategy use, and the ability to effectively match appropriate instructional approaches to a particular problem promotes better training. (Crandall, Pliske & Zsambok, 1998).

There are several theoretical components to the CDE process that are believed to contribute to its effectiveness. First, CDE promotes a collaborative relationship between the trainee and instructor. The best OJT providers have been found to consider the assessment of a trainee s ability and motivation to learn a critical and challenging component of the instructional process. Skilled OJT providers also diagnose barriers to training progress. When this information is shared with trainees, it serves to anchor trainees with an understanding of what is expected of them. Furthermore, prior research on OJT (Crandall et al., 1998; Zsambok, 1997; Zsambok et al., 1996) stressed the importance of getting the trainee to own some of the responsibility for the training process by mutual goal setting, which requires that the instructor and trainee reach common goals for training. Another requirement of collaborative training is the creation and maintenance of a working climate that is conducive to learning. The instructor s primary task during the pre-brief step is to establish an environment that is non-threatening, open, supportive, and that invites honest exchange of views and information from both instructor and trainee (Crandall, Pliske, & Zsambok, 1998).

In addition to collaboration strategies, CDE implements the use of domain specific information to guide the instructor-trainee dyad in diagnosing a performance issue. Cognitive Task Analysis (CTA) is used to classify the cognitive (or mental) challenges needed to perform a particular task. CTA helps to identify this important tacit information, which may facilitate more effective learning during training. CTA provides an alternative approach to more traditional forms of Training Needs Analysis by providing a means for identifying essential processes (e.g., teamwork) that underlie performance outcomes (Salas & Cannon-Bowers, 2001). Traditional Task Analyses can make it difficult to identify these essential processes. Research carried out with a variety of tasks, and in a variety of domains, indicates that a great deal of expert knowledge is tacitly held. This information often involves skills and knowledge so well learned and familiar that the expert may be unaware that he is drawing on them while performing a task (Berry, 1987; Klein & Hoffman 1993; Waterman, 1986). CTA allows practitioners to identify and define this knowledge. Cognitive challenges were identified using CTA on the job of the ADC - Air Defense Coordinator (see Table 1). Each job or task is accompanied by its own unique set of cognitive challenges, such as those created for the ADC position. Different jobs have cognitive challenges specific to the tasks involved, and need to be developed to facilitate the CDE process.

CDE also provides the instructor with a toolbox of instructional strategies that can be used to help unpack the instructor s knowledge. Zsambok (1994) identifies strategies that are typically used in OJT. Flexibility and breadth of strategy use, along with appropriateness of an instructional strategy, is believed to be important for the training process. The CDE framework attempts to increase the repertoire of instructional strategies used by instructors and trainees. CDE also requires the instructor to further diagnose performance according to whether the cognitive challenge identified as a problem was due to a knowing (i.e., declarative knowledge), thinking (i.e., decision-making/problem solving), or doing (i.e., procedural knowledge) problem (see Table 2). Categorizing performance problems into one of these three categories not only aids performance diagnosis, but also guides the instructor in selecting the appropriate instructional strategy from their repertoire.

Certain problem types are best addressed using certain instructional approaches. For example, if the instructor thinks the trainee is struggling because he lacks appropriate declarative knowledge (i.e., a knowing problem), the instructor would implement a knowing strategy such as: Ask the trainee questions about facts, e.g., What did that radio transmission tell you? And, if the trainee does not possess the required level of knowledge of about facts, the instructor would implement a Summarize what you know strategy and share his expertise. However, if the instructor thinks the trainee is struggling because he is not managing his attentional processes effectively (i.e., a thinking problem), then the instructor would implement a thinking strategy such as: Directing trainee s attention, e.g., Make sure you watch this track because... There are additional general strategies that contain elements of knowing, thinking, and doing. Examples of this include, Tell , and Give Feedback. Instructors may use these strategies when the performance issue is not explicitly tied to a knowing, thinking, or doing problem. These strategies are listed on a laminated job aid for the instructor s reference throughout the training process (See Table 3).

	Definition
Building & Maintaining SA	Situation awareness refers to an understanding of his environment. The ADC must understand the Big Picture and be able to communicate it to others. It is difficult to build and maintain SA, because the ADC must fuse information from multiple sources to make a single coherent tactical picture. He must resolve discrepancies in track IDs, filter information, and assess potential threats in order to build a 3D air picture in his head.
Validating ID	The ADC must sort through all tracks to determine validity, and ID as friendly, hostile, or unknown tracks. He does this by gathering, checking, and synthesizing information from multiple sources. This is difficult because it requires the ADC to understand relevant patterns for different theatres in order to make important discriminations among tracks. He also has to be able to deal with differences of opinions from both within his own CIC team and other units.
Prioritizing/Data Filtering:	The ADC must determine what information, or lack thereof, is most important and which tracks are most important. He has to prioritize the immediate threats to own ship. This is difficult because the CIC is a dynamic, time-pressured environment that requires the ADC to make quick judgments based upon the presence or absence of information received, and reliability of resources.
Managing the Air Space	The ADC may be responsible for multiple air assets. He must monitor their safety, weapons, and fuel status. He must be aware of unsafe areas and follow proper procedures if operating within the Joint Engagement Zone (JEZ) or Missile Engagement Zone (MEZ). He must make periodic reports on the status of aircraft under his control to the Tactical Action Officer and the Warfare Commander. This is difficult because the ADC has no direct communications with the aircraft. He communicates with air assets through an air controller. It is also difficult because he must keep all this information in his head.
System Operations	The ADC must know how to operate his system. From console operation to the capabilities and limitations of sensors and weapons systems, the ADC must be well versed with current doctrine.
Gathering Information	The ADC has to gather information from multiple sources local sensors, radio circuits, message traffic, intelligence, and data links. This is difficult because he has to know ***who*** to ask, ***when*** to ask, and ***what*** information to ask for. He also needs to know when to follow-up on his information requests.
Evaluation and Dissemination of Information	The ADC must evaluate the information he receives and determine to whom he should pass this information and when to pass it. This is difficult because some information is critical and requires immediate action; other information needs to be passed on eventually, but not right away. The ADC must anticipate the information needs of the TAO, other team members in CIC, warfare commanders, and other units what do they need and when do they need it?
Multitasking / Prioritizing	The ADC has to listen to multiple channels of information. He is always monitoring internal and external comms, using his hands on the console, watching his display, and making reports. This is difficult because he has to do so many things simultaneously.
Proper Communication Procedures / Phraseology	The ADC must know how to speak clearly, concisely and assertively over the external and internal circuit. This is difficult because the ADC must use code words, which frequently change, and must also know applicable communications procedures for communications security on clear voice circuits.

Table 1. Cognitive challenges identified for ADC position using CTA**.**

KNOWING	*Experienced workers have a broader, deeper knowledge base than novices.* Experts know more than novices, and what they know is more accessible. In many cases, experts automatically know what to do. Experts also know where to find relevant information that is not stored in their memories (e.g., where to find appropriate reference materials, who to ask, etc.). Relative to novices, experts understanding is deeper and more evolved. Therefore, their mental models of the task, equipment, and organizational components of a job are more accurate, more comprehensive, and more integrated.
THINKING	*Experienced workers think qualitatively differently than novices*. Experts are able to recognize important features of the stimulus, and to detect salient features or patterns that novices miss. Experts know how to direct their attentional processes so they can detect subtle changes in their environment. And, unlike novices, they notice what information is missing as well as what information is present. Experts can quickly make difficult judgments based on their previous experience with similar situations. By using their well-developed mental models, they are much more proficient than novices at anticipating future events and planning strategies to deal with those events.
DOING	*Experienced workers are more efficient and effective than novices at performing the procedural aspects of a task*. As expertise develops for a particular skill, performance that was variable or awkward becomes more consistent, accurate, and complete. Experienced workers can carry out standard action sequences efficiently and effortlessly, whereas novice workers struggle through the same sequence of actions.

Table 2. Definitions of Knowing, Thinking, Doing.

Knowing	Doing
Ask questions about facts • What did that RT tell you? Summarize what you know • In accordance with [ROE] you need to Identify reference material • You seem to be having trouble with X, go study Y.	Explain the right way and the wrong way to do things • When you want to get information from X, you need to say Y. • If you attend to channel X at Y time, then you are going to get Z information. That isn t what you want. Break material into smaller pieces • Today let s focus on communications over the external circuit.
Thinking	**General**
Direct trainee s attention • Make sure you watch this track because • During X, it s better to listen to Y channel because... Ask for trainee s SA • At point X in the scenario, what did you think was going on? Ask trainee to explain why/why not • Why did you do X then? • Why did you decide not to say Y? Identify potential problems • What is your biggest concern at the moment? Ask hypothetical questions • If X moves to point Y, what will you need to do? • If the TIC told you X, what would you do? Use examples, analogues, and stories • When I was at X, a similar problem occurred and it turned out like	Ask open-ended questions • What should you say when you hear X? • Why did you ? What just happened? • What is the most important thing on your screen right now? Tell • When the AIC says X you should • When X happens then you should be saying Pass on your experience • When I was in a similar situation, I did... • I ve seen X before Offer prompts • If this is an X type of plane here, what is this? • What should you do next? Give feedback • When you did that, it was absolutely correct. • When you said X, you could have made it shorter.

Table 3. CDE Instructional Strategies for use by Trainers.

Trainees are also provided a list of knowledge elicitation strategies they can use to help unpack the instructor s knowledge. Upon their independent identification of training difficulties, trainees implement strategies during the debrief to gain the knowledge they need to improve their own performance. Trainees may often be aware of the reason for their performance difficulties that the instructor is unable to adequately diagnose. These strategies also increase trainee s ownership over the training process. These strategies are organized into a simple list for use by the trainee (see Table 4). For additional details about the development of the learning strategies, see Pliske et al. (2000).

CDE Training Steps

The CDE program involves a series of training steps completed by a instructor/trainee dyad that are built around the completion of a realistic, scenario-based training exercise. The CDE program provides the instructor and the trainee with recording forms to facilitate the sharing of expertise during the training session. CDE also provides both instructors and trainees with job aids that list of a variety of strategies for improving the transfer of expertise within the training context. Instructors and trainees learn how to use the CDE recording forms and job aids by participating in workshops prior to the training exercises. During the workshops, instructors and trainees receive guidance and opportunities for practicing methods to establish collaborative training relationships. Throughout each step of CDE, both the instructor and trainee are given responsibilities (see Table 5). This section provides a brief description of the steps in the CDE program and the responsibilities associated with each.

The first step in the CDE process is the Pre-brief, in which the instructor and the trainee discuss goals for the training session. This goal setting helps to focus training toward particular objectives and creates challenges for the trainee to meet. This can provide structure as well as motivation for performance.

Clarify expectations
- What are the goals for this training session?
- What should I focus on during the scenario?

Discuss with instructor what could go wrong
- What should I be worrying about?

State where you need help
- I understood part X, but not Y. Could you explain?

Ask again when you are confused by the instructor s explanation
- What s the key difference between X and Y?

Ask for other examples
- So, are there other times when X happens?

Request feedback
- Was that the best way to express X?
- Should I have passed on that information?

Ask instructor questions about his thinking
- When X was happening, what were you noticing the most?
- What would you have done in X situation?

Discuss with instructor if you took action X, what are the likely consequences
- If I do X, what is likely to happen? Why?
- When X happened, how should I have known that Y was going to happen?

Ask for resources to learn off-line
- I m having some trouble with X, what do you recommend that I do or read?

Table 4. Learning Facilitation Strategies for use by Trainees

The second step is the Training Exercise. A great deal of training in the Navy occurs in the context of high-level simulated exercises or scenarios in which the trainee is instructed as part of a larger team. The CDE program was specifically designed for training that takes place in this context. During a scenario or exercise, the instructor observes and assesses the trainee using the CDE s Observation and Assessment Record (OAR) as a guide. The OAR contains a list of challenges identified through prior CTA as being most critical to job performance. The OAR provides a framework for the instructor to begin to diagnose job related process deficiencies that may contribute to negative outcomes. In other words, the OAR is a diagnostic tool that allows the instructor to categorize observed performance problems as a knowing, thinking, or doing related issues. The OAR is used by the instructor to provide on-line coaching, when necessary, and to aid in the debrief following the exercise.

The third step in the CDE process is the One-on-One Debrief Preparation . During this step, the instructor completes the OAR form, adding detail not captured during the real-time exercise scenario. He also uses this time to prepare his training strategy based upon the diagnosis made and guided by the list of training objectives provided to him. Both positive and negative examples of performance are noted. He prepares his comments for the One-on-One Debrief step, which occurs next. The trainee s activities during the debrief preparation are to reflect back on his performance guided by the Trainee Debrief Worksheet (TDW). The TDW is the trainee equivalent to the instructor s OAR. This self-assessment may expose deficiencies that were previously undetected by the instructor. This also allows the trainees to begin thinking about how best to address their deficiencies in the debrief with their instructor and setting future goals for improvement.

In the fourth step, the One-on-One Debrief, the instructor and the trainee discuss what they recorded on their forms to determine where and why the trainee is having difficulties, as well as where his strengths lie. The aim of the discussion is for the trainee to learn, based on his performance during the exercise, how to understand and perform his job better, and for the instructor to effectively access and share his expertise. Discussing trainee strengths in performance is emphasized to encourage the trainee and to provide an overall positive learning climate. The instructor and trainee use debriefing strategies provided by the CDE program to structure this discussion (see Tables 3 and 4). Performance deficiencies are diagnosed as declarative knowledge, procedural knowledge, or a decision-making issues which helps the instructor to select the appropriate instructional strategy, as particular performance issues are best addressed best using particular types of instructional approaches (Table 3). Instructors and trainees utilize both instructional and learning strategies to help unpack the instructor s expertise. The one-on-one debrief concludes with the instructor helping the trainee to determine what they can do after the exercise to improve his job performance and to prepare for the next exercise. Exercises are often distributed over days or weeks, so the CDE debrief includes this opportunity to establish learning goals and strategies that will help the trainee reach those goals on his own.

CDE Step	Instructor Responsibilities	Trainee Responsibilities
1. Pre-brief	• Establish positive learning climate • Identify training goals	• Work with instructor to identify learning goals
2. Training Exercise	• Take notes on trainee s performance using OAR • Determine where trainee needs help • Select and implement training strategies	• Perform training exercise
3.One-on-one Debrief Preparation	• Encourage the trainee to self-assess using TDW • Add additional comments to OAR • Determine where trainee needs help • Select debriefing strategies	• Fill out TDW • Identify key problem areas
4.One-on-one Debrief	• Review TDW • Implement debriefing strategies • Discuss TDW and OAR • Help trainee complete TDW Strategies for Improvement	• Use learning strategies to obtain feedback from instructor. • Discuss TDW with instructor

Table 5. Description of Instructor and Trainee Responsibilities in each of the first 4 Steps of the CDE Process.

FUTURE WORK

A preliminary evaluation effort has demonstrated some positive results for ADC trainee learning over that of a control condition in a low fidelity simulation. However, for successful transition of CDE to the fleet, further evaluation and refinement of CDE s mechanisms for shaping performance must be completed. CDE s training effectiveness must also be evaluated across the four different levels of training outcomes ranging from trainee reactions, trainee learning, transfer of learning job, and organizational outcomes (Kirkpatrick, 1994). The following paragraphs outline some of this future work.

First, from initial tests, it is difficult to determine which underlying mechanisms were responsible for the positive results. Tests should be conducted to isolate each process to determine which are effective, and on which types of performance outcomes. It may be found that only part of the CDE process is responsible for learning found and modification of the CDE process may be warranted.

Second, it should be examined whether CDE is appropriate for less experienced, as well as more seasoned, trainees. Results here can help to determine where best to place CDE intervention in the training pipeline for maximum impact on performance and benefit to the Navy.

Third, what types of jobs are most suitable for CDE training intervention? CDE s targeted challenges tend to be higher level, unpredictable, and dynamic in nature. The ADC job is cognitively demanding primarily due to the enormous demands placed on working memory. Future research needs to explore whether CDE is effective for other types of positions requiring less cognitive tasks. A taxonomy of target task characteristics suitable for CDE intervention should be created.

Fourth, CDE should be evaluated in a high fidelity training situation to verify whether effects found using a low fidelity simulation are still evident, and whether other effects may be manifest in a more cognitively rich environment.

Fifth, CDE effectiveness should be tested in team training environments. CDE originally contained six total training steps. The final two steps involve a team-training component, and were not discussed in this report. A team-training environment would provide the opportunity to evaluate the steps of CDE that promote teamwork. This research could also explore the degree to which CDE is compatible with other team training programs, such as Team Dimensional Training.

Sixth, the amount of preparatory training required for the instructor and trainee to effectively implement CDE should be determined. In the preliminary validation, while manipulation checks indicated that the CDE process was being utilized, it was often not used to its fullest potential. How much additional training would be required to optimize CDE use, and where is the point of diminishing return? Similarly, up to this point, most of the focus has been on providing the instructor with tools necessary for CDE. Further work needs also to examine ways to improve the trainee s role as a knowledge elicitor.

Seventh, measures used to assess CDE learning should be refined and further validated. Valid measures of performance are needed for a complete training package. These measures probably will differ from those currently used in Navy training, as CDE is

designed around improving the underlying cognitive processes associated with a task. Currently, most measures of performance in the Navy focus on performance outcomes. Furthermore, criteria for satisfactory performance should be set and these criteria should reflect current or future Navy standards.

Finally, CDE should be evaluated across all four levels of training effectiveness as defined by Kirkpatrick (1994). These levels include: (1) Trainee reactions such as self efficacy, perceived leaning climate and positive feelings toward training; (2) trainee learning of the tasks through the CDE process; (3) trainee transfer of learning to their performance at their job; and (4) organizational outcomes such as training efficiency and return on investment to establish that CDE provides organizational benefit.

CONCLUSION

Preliminary results show promise for CDE as a training intervention for complex tasks. Along with the aforementioned proposal for future work, plans should begin for transitioning CDE to appropriate Navy environments once CDE is validated. This will help to insure that CDE s full benefit as a low-cost solution for effective training will be realized.

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