Cognitive Processes Embedded in Self-Explanations of Solving Technical Problems: Implications for Training

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This qualitative research examines the cognitive processes embedded in self-explanations of automobile and motorcycle service technicians performing troubleshooting tasks and solving technical problems. In-depth interviews were conducted with twelve service technicians who have obtained the designation of "master technician" or equivalent within their work environment. Cognitive processes revealed include: self-talk, visualization, linear and hierarchical thinking, use of job-aids, rule application, and the learning incidences that occur through social contact. Implications for training are discussed.

Keywords: Metacognition, Troubleshooting, Technician Training

Automobile and motorcycle service technicians work in dealerships repairing vehicles. Technician efficiency and productivity are vitally important to the individuals because their pay is based on these measures. The efficacy of their work is also very important to the owner of the dealership because the service department is a major contributor to profitability. Dealers/owners value skilled service technicians, in part, because the mechanical, electronic, hydraulic and structural systems (and problems) are becoming more complex while the overall quality of the vehicle is increasing. The steady demand for good service technicians is influenced by this increase in complexity of vehicular systems and influences the staying power of the dealership as the retail outlet for customers. The impact of this industry on the American economy is considerable. Motorcycle ownership increased in the U.S. from an estimated 6.5 million in 1998 to 8.8 million in 2003, an increase of 26% (Motorcycle Statistical Annual, 2004). In spite of recent shake-up in the American auto industry, over 51 million new and used cars were sold across the country in 2003 (Bureau of Transportation Statistics).

Demand for high quality service technicians is strong. According to the U.S. Department of Labor (Bureau of Labor Statistics, 2005) over 800,000 auto service technicians worked in 2004 and the demand is expected to grow. Employment opportunities should be very good for service technicians and mechanics with diagnostic and problem-solving skills and knowledge of electronics and mathematics. There is, however, some debate in the service industry as to whether there is a shortage of technicians, or a shortage of high quality technicians. Either perspective infers the need to train more high quality service technicians and provide support to those in the field.

Research Problem

In order to train high quality service technicians to perform diagnostic and problem-solving tasks in the automotive and motorcycle service industry, carefully designed training strategies need to be in place. To accomplish this, a rich description of technician thinking about the diagnostic process is essential. Therefore, the purpose of this research was to identify the cognitive processes embedded in self-explanations of service technicians when describing what they think when solving technical problems. Rich descriptions of their work and their explanations of how they thought about this process is required. The answers of service technicians to basic questions about what they thought made them good at trouble-shooting technical problems, and what and how they think while trouble-shooting technical problems were sought.

Work Setting

The typical work process at automobile and motorcycle dealerships begins with the customer's explanation of a problem to a service writer. This information is recorded on a repair order and given to a technician who diagnoses and repairs the problem. The technician records the amount of time spent and parts required for the repair. A cashier presents the invoice to the customer. Master technicians tend to be assigned more difficult problems in the service area at any given time. This is primarily because their skill enables a faster repair than less experienced technicians who can be assigned more routine service tasks.

The overall nature of service work is to balance the processes of replacing parts in a vehicle or repairing faults. Each strategy is influenced by variables of time, money (cost to the customer, profit to the dealership, and pay to the technician), and customer satisfaction. Technicians generally receive training from multiple sources using a variety of training delivery modes. Good technicians are highly valued by their managers and dealership owners.

In the United States, the automobile and motorcycle service work environment is characterized by how technicians are paid. Some are paid straight time on an hourly basis. Most are paid at flat rate, or the amount of time allocated by the manufacturer to make a specific repair. For example, if the manufacturer allows 30 minutes to test and replace a part, the technician is paid that amount based on his/her hourly rate regardless of how long it actually takes the technician to perform the work. Talented technicians may be able to perform the work in 20 minutes but will get paid for the 30 minutes allocated. This enables some technicians to perform at more than 100% efficiency in a given day. Some technicians are salaried receiving a weekly amount of pay negotiated with the owner of the dealership. Technicians are paid for individual productivity therefore there is limited interaction on specific tasks with co-workers. The opportunity for apprenticeship with co-workers is limited in this environment but some senior technicians serve as good examples of work ethic while occasionally providing informal consultation and advice. Outside experts can contribute much to teams solving technical problems. A modification to this approach can be found in the dealership. Product manufacturers provide technicians with hotline assistance. However, technicians use this service infrequently due to the procedures hotline experts require technicians to follow and/or the perceived value of such a call in actually solving a problem. It seems that technicians will call hotline experts when all of their strategies fail to solve the problem.

The technicians regularly use computer-based reference materials and less frequently, special technician hot-lines established by the manufacturer. As a normal part of their work, service technicians use a variety of diagnostic tools and instruments. Although affiliated with a manufacturer, all automobile and motorcycle dealerships participating in this study were privately owned.

Although the actual problems vary between automobile and motorcycle service, each involves knowledge of the product and specific systems and sub-systems within the vehicle, knowledge of diagnostic procedures and awareness of recent service bulletins from manufacturers. For example, some of the recent problems identified by technicians were: Automobile headlight wiring was previously altered to turn-off daytime headlights and this caused problems with high/low beam functioning; another problem described by technicians was that a “Check Anti-Lock Brakes” light appeared on the instrument panel after service to replace a brake module found a loose ground on an electrical connector and repaired it. Motorcycle technicians reported a recent problem when a 3rd party exhaust pipe caused vacuum leaks that effected the carburetor and a replacement carb kit did not resolve the problem.

Theoretical Framework and Background

Problem-centered training occurs in various settings for service technicians. This provides rule-based procedures, expert assistance, and experience to practice. Common industry practices illustrate that many technicians attend technical training program prior to employment and that in-service technicians receive training from manufactures’ school (such as General Motors, Ford, Audi, or Saab) independent industry training schools (Firestone, Sears), and equipment/vendors (makers of scan tools, gas analyzers). Most training is expert/trainer facilitated, some self-study.

Service technicians individually inspect, maintain, diagnose problems and repair vehicles (cars and light trucks) and motorcycles (2 wheel and ATV) powered by gasoline, diesel, electric & hybrid energy sources. To diagnose technical problems of increasingly complex machines require fluid and adept cognitive functioning. How one thinks about this process is important.

The link of metacognition to skilled thinking is related to the “awareness and management of one’s own thought” applied to the performance of complex tasks (Kuhn & Dean, Jr., 2004, p. 270). There are opportunities for technicians to consult computers for performance support or coaching, or to call a hot-line. This form of electronic task performance support is acknowledged by some to provide important interaction with task-specific content that may contribute to increased problem-solving ability (Wilson, Jonassen, & Cole, 1993; Gery, 1995). The organization of knowledge within contemporary electronic performance support systems used by service technicians is arranged around specific sub-systems or components such as an antilock braking system or a specific electrical connector, rather than concepts. According to Wyman & Randel (1997), this level of knowledge organization fails to provide the capacity to perform complex cognitive tasks. They found that technicians who perform tasks at high or intermediate levels were more likely to have a conceptual understanding of their content than those technicians who accomplish tasks at a low level of performance.

The contribution of self-explaining problem-solving performance made by Neuman, Leibowitz, & Schwarz (2000) provides useful insight into how school aged children use language to influence cognitive functions and solve complex problems. However, Winsler & Naglieri (2003) describes situations when self-talk may not be related to task performance of older children (less than 18 years of age). Clearly, the relationship between self-explaining and self-talk when solving problems is not fully understood in working adult populations.

The procedural function of metacognition (awareness and management of thinking) appears to be important to address in the design of effective training strategies. So too is understanding the declarative function of metacognition or broader understanding of knowing (Kuhn & Dean, Jr., 2004). Technicians tend to benefit from an active way of knowing, or praxis, that involves the use of tools, materials, energy and diagnostic devices in a constructivist manner loosely based on an "if this, then this" paradigm.

Undertaking the Study

Thirteen male master service technicians were interviewed for this research. Subjects worked at automobile or motorcycle dealerships in the Mid-West. Interviewees were identified as master technicians by their service manager based on criteria established by the manufacturer whose products they sold and serviced. (Most manufacturers require service technicians to have extensive basic training, product-specific training, annual new-product training as well as several years of experience to become master technicians.) Most master technicians have also passed performance-based tests associated with their training. The automobile manufacturers were: Ford, Chrysler, General Motors, VW/Audi, and Nissan. The motorcycle manufacturers were: Harley-Davidson & Buell, Yamaha, Suzuki and Kawasaki. Subjects' experience ranged from seven years to 40 with a mean of 20 years of experience.

Interviews were conducted at the place of employment in the lunch room or conference room and lasted between 50 and 70 minutes. The interviews were audio taped. The interviews were semi-structured and were designed to gather each man's perspective about their work. Two basic questions provided focus to the interview: (a.) What do you think makes you good at trouble-shooting technical problems? (b.) What and how do you think while trouble-shooting technical problems? After each interview was conducted, the researcher summarized and repeated key points provided by the interviewee, asking if the information collected was intended and correct. In all cases, the interviewee agreed that this was so.

Data was analyzed using methods described in the literature on qualitative research (McMillan & Schumaker, 1997; Merriam, 1998). The researcher read and re-read the interview transcripts, making notes in the margins in an effort to uncover underlying themes and returning to the data to check for accuracy using a iterative process designed to uncover meanings. In order to ensure validity, a peer de-briefer with experience as a service technician, trainer, and researcher (PhD in Education) was employed to examine the data and ensure credibility after the themes were initially described. This process lead to theme identification.

Interview Themes

Overall, technicians believe their motivation, experience, technical knowledge, personal habits of work and mind, and appropriate diagnostic tools make them good troubleshooters. Their responses can be sorted into six (6) categories.

Motivation

The emphasis on individual performance as a source of personal prode was apparent through the interviews. Participants describe their attempt to "beat Flat rate," to consider the problem as a "personal" affront to their skill, or as a source of their "passion for this business," and, to some extent, being the hero, "if I can't fix it, who's gonna fix it." Some technicians explained that they were good at troubleshooting because they were motivated. Bill expressed that he was "motivated about beating Flat rate," while more abstract motivations were described by Mark as "being hard headed, I won't stop. It gets personal." Sam said "well, I always had the philosophy, that when they bring it here, I just felt that I was the last guy at the end of the line. If I can't fix it, who's gonna fix it? " Personal traits were also described as a reason for being good at troubleshooting. Rich said, "I have a tendency to ask a lot of questions, then try to reproduce the problem myself," and "the best trouble shooters have a passion for this business."

Experience.

Common explanations of success in trouble-shooting were provided in ways that credited experience as a teacher, such as, "knowing the basics," "check the basic stuff" and "experience." Larry said what made him good at trouble-shooting was "experience." Sam also stated that it was "experience." Describing what makes him good, Bob said that he was "not always looking for the easy way out." Larry said that what made him good at troubleshooting was, " I have a knack for it, intuition."

*Technical knowledge and system thinking***.**

It was apparent that a deep understanding of the vehicle's systems was the foundation for their problem-solving ability. Explanations of their success were frequently embedded in the belief that the vehicle was comprised of numerous components and systems acting or waiting to act. Dick explained that his ability to solve complex problems was "knowing the basics." Tom described it this way, " I kinda place myself into the car, now I'm flowing through here (powerwire) . . . ," Tom explained his process this way, "I can think - if this, then this." Larry stated that he used "observation, just looking for it" and that he would remind himself to "check the basic stuff, you know, check your fuses." Art's description agrees with Larry's by saying "listen to it . . . usually an idea will pop into your head right off the bat." Rich added, "So to me, I figure out what I expect to see, then see if I've got it." Observation and listening infer expectations about component or system behavior and then referencing malfunction behavior to these expectations.*Internal linear and hierarchical thinking*

Comments that demonstrated participants' metacognition were evident while troubleshooting. They were exemplified as "I kinda place myself in the system," "I think of things like a spider-web with lines connecting," and establishing perspective on the problem by, "I'll just stop, sit around for a second and go back," demonstrates thinking of active ("doing") individual components while simultaneously thinking in holistic and expanding systems. Keeping a perspective was explained by Art as making him good at troubleshooting because he was "able to walk away from it (the problem)" and clear his head. Some subjects believed that their work processes enabled them to be good at troubleshooting as their training was based on a linear four or five step process. Adding an explanation of one technique that has worked on very difficult problems, Art went on to say, "And the thing that gets me, is you can be beating on this thing for an hour, or six hours, and then walk away and when you come back, you got it. Sometime I'll go to the bathroom." In a way, Sam offered a similar description when he said, "A lot of times you're working on something and you're not getting it. I'll just stop, sit around for a second and go back and usually it goes right back together." Bob said, "I think of things like a spider-web with lines connecting things." Iterative linear and hierarchical thinking was important for vehicle problem-solving and troubleshooting.

Mental imaging and self-talk

Some interviewees described their thinking by saying, "I guess its kinda a voice," "I see pictures," "I talk to myself" and "with mechanical problems I'm visual and with electrical-type problems I think in lists and drawings." What pops into Art's head was this, "I guess its kinda a voice, it says, you know, go check this first. Sometimes I can picture how things work." Tom described 'what and how' he thought while troubleshooting this way, "I kinda place myself in the system, like the powerwire . . . I'm going through the event to see if this ain't happening. I put myself into the car, now I'm flowing through here . . ." Other technicians also made references to visualization. Mark said, "I see pictures. I'll see the pages in the books sometimes, some of the pictures and diagrams, wiring schematics – some of them hand drawn. I'll draw them in my head , this wire goes here . . . " Rich said, "I talk to myself," and, "I think with mechanical problems I'm visual, and with electrical-type problems I think in lists and drawings." Successful technical diagnosticians engage in mental imaging as well as self-talk.

External diagnostic tools and references

Technicians reported they touched and physically manipulated devices, "use the computer," use a "scan tool," and called the service "hotline." Jack explained his success that it was "being able to use the computer," and Mark said "scan tool that has 'pin-point' diagnostics" were frequently used diagnostic tools. Sam attributed his success to being able to "get a trouble-code and you go back and print out that procedure [to solve the problem]." Trouble-codes are identified after the technician uses a scan tool that is connected to the vehicle's electrical system. Codes frequently found are easily recognized by the technician and lead to common repairs. Infrequently seen codes are entered into a computer for explanation. Some manufacturers require service technicians to interact with a guided diagnostic software program running on a laptop. The intent of this procedure is to provide factory-specified diagnostic steps and ensure uniformity of service across the country. Evidence of the technician's use of such software becomes the basis of his/her pay.

Conclusions and Recommendations

Master service technicians engage in complex cognitive functions while performing technical problem-solving and troubleshooting tasks. Processes associated with executive functioning and cognitive strategies such as using inner dialogue, attending and encoding are especially important to their work. Some social learning occurs in the workplace but more tends to occur outside of the workplace. The use of cognitive tools such as concept mapping and questions-generating are also very important. In addition to incorporating these skills into training, other implications for training and education include: a. apply non-linear instructional design within rule-based learning, b. focus on procedural and declarative metacognition functions, and c. incorporate self-explanation within training as a way to improve metacognition among service technicians. Developing these cognitive skills are critical to the improvement of the 21st century technical workforce.

Contributions to New Knowledge

This research builds on existing literature as well as hints toward some new knowledge about how and what technicians think when performing diagnostic tasks. Connections to existing strategies and research themes were found:

- Use of self-regulating strategies – technicians are aware of their thinking when solving technical problems and regularly shift from linear thinking to hierarchical or holistic thinking.
- Posses strong connection to possessing a "feeling-of-knowing" and "willingness to continue" as a control and monitoring device – confidence in knowledge and ability is evident as well as strong motivation to solve problems.
- Follow retrieval of knowledge theory consisting of recall and precision – active management of thinking enables technicians to use and apply extensive knowledge and facts to specific situations.
- Engage in problem-solving framework more complex than math problem-solving: orientation, planning, executing and checking – the dynamic nature of complex technical systems require technicians to shift the output metrics of system performance as sub-repairs are made.
- Use working memory and long-term memory – the awareness of current conditions in vehicle sub-system performance is referenced to known specifications or expectations as diagnostic procedures as executed.

New knowledge about adult workers, specifically those who perform technical service work, illustrates that they may engage in problem-solving procedures that differ from younger subjects and that some form of flexible thinking between linear and hierarchical thinking occurs. In addition, the composite performance attributes of motivation, experience, technical knowledge, personal habits of work and mind, and appropriate diagnostic tools make good troubleshooters. These attributes are especially important when performers are cognizant of how and what they think while performing tasks. These findings have powerful implications for HRD professionals who train technicians as well as those who train trouble-shooting and diagnostic skills. Instructional design that incorporates system thinking, linear and hierarchical thinking, mental imaging and self-talk as well as the integration of diagnostic tools and references in a synergistic manner is essential in training high quality technical diagnosticians.

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