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Dreyfus Five-Stage Model of Adult Skills Acquisition Applied to Engineering Lifelong Learning

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Tools for Assessing Level of Expertise and Determining Appropriate Instruction, Assignments and Feedback to Enhance an Employee's Human Capital

Introduction

Guiding employee development is an important managerial role. As with many professions, the training engineers receive in college is formal and dictated by college curriculum requirements. But once engineers enters the workforce, the majority of their learning is informal[1,2] and is self-directed with guidance from their manager. For managers to be successful at helping employees develop skills, they must be able to assess an engineer's current level of expertise and determine what type of instruction, assignments and feedback are most appropriate.

This article looks at the Five-Stage Skills Acquisition Model by Dryfus,[3] which has been applied to lifelong development of doctors, and applies it to the development of engineers. The purpose of this paper is to introduce two rubrics that can be tools for engineering managers to help them guide the learning and development processes for their employees resulting in an increase in their employees' human capital. The purpose of the two rubrics is to assist managers in determining the current level of expertise of their employees and to determine how to direct their development and raise their employees to a higher level of expertise.

Dreyfus Five-Stage Model of Adult Skills Acquisition

The Dreyfus Five-Stage Model of Adult Skills Acquisition is grounded in the argument that "skill in its minimal form is produced by following abstract formal rules, but that only experiences with concrete cases can account for high levels of performance".[4] In the original paper written by Stuart and Hubert Dreyfus in 1980, the five stages of expertise were named novice, competent, proficient, expert and master. The model focused on four mental functions:

recollection, recognition, decision and awareness and how they varied at each level of expertise. Each time a mental function matures, the individual's level of expertise rises. The Dreyfus brothers hypothesized that to obtain the level of master one first must progress through the lower levels of expertise.[5] The model is based on learning a skill not a profession. For example, a computer engineer can be a novice in networking and an expert in Java programming. Table 1 is taken from their 1980 article and summarizes the model.

Table 1. Mental Functions for Each of the Five Levels of Expertise in the 1980 Article

Mental Function	Novice	Competent	Proficient	Expert	Master
Recollection	Non-situational	Situational	Situational	Situational	Situational
Recognition	Decomposed	Decomposed	Holistic	Holistic	Holistic
Decision	Analytical	Analytical	Analytical	Intuitive	Intuitive
Awareness	Monitoring	Monitoring	Monitoring	Monitoring	Absorbed

In a later article written only by Stuart Dreyfus in 2004, the five levels were referred to as novice, advanced beginner, competent, proficient, and expert. Instead of using recollection, recognition, decision and awareness to differentiate the levels, he used component, perspective, decision and commitment.[6] This article is more widely referenced in published articles and will be used in this paper. Table 2 is taken from the 2004 article and summarizes the model.

Table 2. Levels of Expertise in 2004 Model

	Novice	Advanced Beginner	Competent	Proficient	Expert
Components	Context free	Context free and situational	Context free and situational	Context free and situational	Context free and situational
Perspective	None	None	Chosen	Experienced	Experienced
Commitment	Detached	Detached	Detached understanding and deciding; involved outcome	Involved understanding; detached deciding	Involved
Decision	Analytic	Analytic	Analytic	Analytic	Intuitive

In the above table, components refer to the "elements of the situation the individual is able to perceive".[7] Perspective refers to choosing which elements or situations of the problem are important to focus on. Commitment refers to how personally involved the individual is in the outcome of the learning situation, as well as understanding and deciding how to address the issue. The final component is how individuals make their decision-using an analytical process or intuition.

According to Dreyfus, individuals must progress through each stage of expertise and must draw on their experiences of solving problems in context to reach higher levels of expertise. Each time individuals acquire a new skill, they start at the novice stage where they need to learn the facts and the rules for determining action. In school situations, instructors help by reducing big problems into small pieces that can be solved without knowledge of the entire situation. In work situations, this step is more likely to be informal and might take place through observations or self-teaching. The novice thinks through the analytical process and decides the course of

action to take to solve the problem. Since novices generally do not have responsibility for outcomes, they have a detached commitment.

For individuals to move to advanced beginner, they must have practice applying the facts and rules to real situations. This enables them to start associating the facts and rules with context that can be relied on in the future. The instructor/manager can refer to these situations as well as the facts and rules to continue to advance each individual to a higher level of expertise.

Competent individuals still refer back to the rules and use analytical processes; but at this level, since the problems encountered are more complex and do not follow a textbook script, each individual relies on their past experiences to decide which elements of the situation are important. They then focus on these elements to solve the problem. Since the individual is starting to use personal judgment by determining which elements are important, they begin to develop an emotional investment. Dreyfus hypothesized that when an individual invests emotionally by taking responsibility for success and failure in making correct decisions, a higher level of learning takes place. This is what limits the advancement of expertise in a school environment, as few projects are implemented and therefore do not involve consequences of failure or rewards of success.

Proficient individuals start to draw on their emotional experiences from successes and failures to help them determine which elements of the situation or problem are important to focus on. At this stage, the individual continues to increase risk taking and commitment to the outcome. The individual knows what needs to be done, continues to rely on rules and an analytical decision making process, but experiences plays an increasingly important role.

At the final stage of expertise, expert, the individual not only sees what needs to be done but also sees the solution without having to go through an analytical process to arrive at the solution. At this level the individual is totally immersed in understanding the situation, making decisions on how to proceed, and in the outcome of the situation. They could not have arrived here without progressing through the previous stages of skill acquisition and accumulating experiences and emotional involvement.

Application of Dreyfus Model to Medical Education

The Dreyfus model has been applied to sports,[8] ski instruction,[9] soldiers,[10] public health,[11] virtue,[12] computer programming,[13] ethics[14] as well as the education of doctors.[15,16,17] Within the medical profession the model has been widely adopted as a method of assessing students and residents as they proceed through their studies of clinical medicine.[18] As with engineers, doctor's skill development begins in college and progresses through their careers. Table 3 summarizes the characteristics of a medical student/doctor at each level of expertise. The information in the table is taken from an article by Carraccio et al.[19] It is critical for the instructors/supervisors in clinical situations to recognize which stage of expertise an individual is in. It would be devastating to allow a junior medical student to diagnose a patient using his intuition based on a minimal amount of experience.

Table 3. Medical Education Application of Dreyfus Model

	Who Is in This Stage	Characteristics
Novice	Freshman medical student	They are taught by an instructor about elements, illnesses, systems and how to perform tasks such as taking a patient history. The students focus on learning the facts and the instructions for the task and not the diagnosis of the presented problem. All information is gathered since the student does not have the ability to filter out what information is important
Advanced Beginner	Junior medical student	As they spend some time with patients, they start to see common situations in real life and start to rely on these experiences when faced with similar situations.
Competent	Resident physician	As they start to plan the care for the patient, they learn through their experiences and the emotional involvement with their patients. Since they choose the plan of treatment, they begin to be more committed and their decisions start to involve risk. But they are not yet in a position to accept full responsibility since someone is still reviewing their treatment decisions.
Proficient	Specialist physician	They are responsible for the outcome of their decisions and thus have greater emotional involvement and develop a deeper level of understanding. They increasingly draw on their experiences.
Expert	Mid-career physician	Throughout their schooling and career, they have learned through many real interactions of treating patients and the results of their treatment plans. They now know how to recognize a pattern of symptoms and then use intuition to decide how to treat the patient.

Dreyfus Model Applied to Engineering

The Dreyfus model can be applied to an engineer's development in a similar fashion. Table 4 shows characteristics of each level of expertise for an engineer. The idea for the rubric and most of its components are taken from the Institute of Conservation's Professional Standards for Conservation.[20] The content of the rubric has been changed to apply to typical engineering

applications. The purpose of this rubric is not to look at the all-encompassing expertise level of a profession or position; he purpose is to evaluate the expertise of a particular skill, theory or principle. For example, by using this rubric, a manager would not evaluate whether a person was an expert quality engineer. Instead a manager would use it to identify what level of expertise the engineer had in a particular function such as designing supplier quality audits.

The rubric is a useful tool for a manager to decide what level of expertise an engineer is currently in, which in turn can help the manager determine what type of assignment, instruction and feedback an employee needs (see Table 5). For example, to get an individual to the novice stage, an instructor/manager should either teach the basic skill/theory/principle or allow time and resources for the individual to learn them, rather than assuming they already know them. This is a very different type of instruction then needed to move an individual from proficient to expert. In that situation the manager should be focused on encouraging the individual to draw on their experiences and help build their self-confidence to use their intuition to solve problems.

Table 6 shows an example of an individual's progression from novice to expert in designing a circuit and what assignments, instruction and feedback are appropriate. As with many skills an engineer develops, the progression for this skill starts in college for most electrical engineers and continues into their professional career. If would be unwise to assign a college co-op student full responsibility for a complex design that was going to be manufactured and it would be a waste of talent to have an expert at circuit design reporting to someone else who has the final authority over the design that is manufactured.

Table 4. Rubric to Determine Current Level of Engineering Expertise

	Novice	Advanced Beginner	Competent	Proficient	Expert
Knowledge	Is familiar with the skill/theory/principle. Knows the basic concept behind the skill/theory/principle and applies it when given the situation and explicit instructions to apply it.	Can determine which skill/theory/principle to apply to different situations without guidance, but not aware of how to optimize its application or other factors that should be considered.	Can identify factors to consider in application outside of the obvious. Can give a few examples of application.	Knows how to optimize the solution for a given content. Can give examples of specific applications and the outcomes	Has an all encompassing understanding of the skill/theory/principle and all issues involved with applying it to different situations. Can give examples of related personal experiences and what was learned.
Standard of Work	Can complete a simple application if given detailed instructions.	Can complete straightforward application with minimal instruction.	Can complete assignment, but not necessarily optimally.	Can optimize solution, but takes some effort	Optimizes the solution without effort.
Autonomy	Can apply skill/theory/principle with guidance, needs feedback to learn.	Can apply skill/theory/principle, to individual assignments, but needs supervision to ensure solution fits into overall project.	Can apply skill/theory/principle successfully and knows there are outside issues that need to be considered, but consults others for guidance on how to address them.	Can optimize the solution and knows the outside factors to consider without asking others	Needs no supervision or support. Others come to them for advice.
Decision	Uses an analytical process to solve the problem using predetermined resources and applies a predetermined skill/theory/principle to the problem.	Uses an analytical process to solve the problem and decides which skill/theory/principle to use to solve the problem.	Uses an analytical process to solve the problem. Thinks about outside factors that might affect the outcome and decide how to address them.	Uses an analytical process to solve the problem. Thinks about how to optimize the solution in the big picture	Relies on intuition to solve the problem. Doesn't have to think about which skill/theory/principle to use or the outside factors affecting the outcome.
Perception of Context	Considers no other factors than the minimal ones given in the problem definition.	Considers the detailed context described in the problem definition, but no factors outside of the problem definition.	Considers factors outside of those defined in the problem that might have a direct impact on success.	Considers how the solution fits into the big picture	Has an all encompassing view of how the solution will impact the big picture.

Table 5. Suggestions for Appropriate Instruction, Assignments and Evaluation to Get Individual to Given Level of Expertise

	Novice	Advanced Beginner	Competent	Proficient	Expert
Instruction	Teach the skill/theory/ principle	Teach how to decide when to use the skill/theory/principle	Teach other things to consider when applying theory, content driven example, mistakes that have been made and consequences to other people and teach how to optimize the solution though example applications that were and were not optimized and the "cost" of nonoptimization	Encourage individual to reflect on personal experiences and observed experiences of others focusing on what did and did not produce desired outcomes and the impact of decisions	Encourage individual to draw on personal experiences applying the skill/theory/principle, both their successes and failures and encourage self-confidence to use intuition to solve problems
Purpose	To teach the underlying skill/theory/ principle, the background, meaning etc.	To teach how to know when to apply the skill/theory/principle to situations that might present themselves	To teach the process of looking at the big picture and how the work affects and is affected by factors not part of the skill/theory/principle	To teach how to draw on personal experiences and the experiences of others to create images and foster memories of application in context	Encourage self-confidence to use intuition
Assignment	Problems applying a specific skill/theory/principle to a very specific situation	Give multiple situations and have individual choose which skill/theory/principle to apply	Project with a real company/product, where individual comes up with the solution to a real problem and presents it to the company	Project where the individual comes up with the solution and sees its implementation after someone else has approved it	Project where the individual is held fully responsible for the decisions made and the outcome of the project and where the project is related to past experiences so individual can draw on success and failures on similar projects.
Purpose	Reinforce the interworking of the skill/theory/principle and how components/variables relate to each other	To bring context to the problem solving process and to practice looking at a situation and determining what skill/theory/principle to apply in what context	Increase experience applying the skill/theory/principle in a new and unique context. Start to develop the ability to look at how the proposed solution affects other aspect of the bigger picture and increase emotional investment/ ownership in the solution	Increase experience applying skill/theory/principle in new and unique contexts and seeing results of proposed solution will start to create emotional memories of success and failure	Create a situation with total commitment and responsibility for the outcome and the emotional investment is high
Feedback	Instructor/supervisor supplied one correct answer	Instructor/supervisor supplied one correct answer	Project supervisor/teacher feedback (no one right answer)	Project supervisor feedback and outcome of the project	Outcome of project

Table 6. Example of Assignment, Instruction and Feedback for Different Levels of Expertise of Designing a Circuit Board

	Instruction	Assignment	Feedback
Novice	Explain Ohm's Law and what each of the variables are	Create problems where the current and resistance are given and the individual is asked to calculate the voltage	Inform the individual whether the answer is right or wrong
Advanced Beginner	Explain when Ohm's Law is used when designing a circuit	Design a simple circuit where the individual has to determine that application of Ohm's Law is appropriate	Inform the individual whether the answer is right or wrong
Competent	Explain what factors are important to consider when designing a circuit board for a particular application, for example design would be different if cost minimization or longevity were primary objectives	Design a circuit board for a particular application that could be made under constraints of cost, availability of parts, etc.	Explain what is good about the design and what could be improved
Proficient	Instruct engineer to review past quality problems and issues producing similar products used in similar applications	Optimize a design of a circuit board that will be manufactured and used in a particular application	Feedback from project manager on corrections or changes to ensure effectiveness and efficiency of the design
Expert	Encourage individual to reflect on other projects and what was learned from the outcomes	Total responsibility for the final design of a circuit board for a particular application that will be manufactured	Does the circuit board work, are there quality / production / longevity issues, was the budget met?

Conclusion

The development of an engineer is an ongoing and lifelong process. Although engineers are responsible to acquire the skills and knowledge needed to be effective in their jobs, their manager must be aware of her employees' level of expertise in different areas and be able to guide them and give them resources to acquire higher levels of expertise. The evaluation rubric and suggestion matrix presented in this paper can be useful management tools to assist managers in identifying an employee's level of expertise and provide the correct type of assignments and feedback. These tools along with the knowledge of the need for the progression to start at novice and systematically progress through the levels of expertise should help create better engineers and better outcomes both at the professional and student levels.

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