Work in Progress - Adaptive Expertise: Beyond Apply Academic Knowledge

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Abstract - A common attribute related to expertise is the speed and efficiency experts display as they apply what they know to solve novel problems in their domain. Much of our assessment methods focus on this ability to process information quickly and identify solutions to common problems as a display of competency in a particular skill and/or depth of domain knowledge. However, as we review certain examples of expertise we begin to see that this fluency only provides one dimension of the kinds of expertise students should display after graduation. In some cases students may only be able to displaying “routine” expertise for specific problems. We want our learners to have flexible knowledge that allows them to invent ways to solve familiar problems and innovative skills to identify new problems. We suggest that the more desirable definition of expertise relates to students “adaptive-ness” to identifying and solving novel problem. This display of “adaptive expertise” ultimately leads to students’ depth of knowledge and habits of mind that lead to success in their career and enable them to be innovators in their field. This paper explores the characteristics of adaptive expertise and its implication for instruction and assessment in undergraduate engineering education.

Index Terms – cognition, expertise, instruction, assessment

EXPANDING EXPERTISE

Learning to use knowledge flexibly and adaptively is more than applying basic skills to short problems. Many standardize assessments do a reliable job of measuring students skills, but is this the only abilities we expect of our learners? What are the characteristics of what students should now and be able to do by the end of their formal education? In this paper we reflect on the aspects of expertise to help inform our thinking our goals for instruction and the implications for designing instruction and assessment. A recent issue of the Educational Researcher [1] provides a review of some of the expertise literature and raises important distinctions about expertise that we feel need to be highlighted to better understand how to design instruction, assessments and curriculum. For example, a key distinction about expertise raised by Hatano [1,2] from observing expertise of experts performing procedural tasks. He noted that these experts were very fluent and efficient at displaying their skills for an activity which they have years of experience. However, some experts fluency decreased when the situation change. For example a cook who is missing ingredients or a farmer faced with their first drought could not decide how to change their procedures. Still, other experts were able to adapt to these change in conditions by defining and alternative procedures. This difference between displays of expertise illustrates “expertise of the routine”, or routine expertise, versus what Hatano calls “adaptive expertise”. He noticed that the experts with conceptual understanding for why a procedure worked were able to invent new procedures when the old ones failed. This is consistent with the expertise literature that highlights experts well organized knowledge structures [3].

The distinction between these types of expertise has implications for defining learning outcomes, designing instruction and constructing assessment measures. Instructional goals need to be clear about which type of expertise is the final outcome. Expertise of the routine is expected of all experts, but in some situations learners only need to be trained in a specific context when the context for their knowledge does not change. Therefore, the goals of instruction do not require a high level of adaptiveness. The assessment of these skills can be done within the specific context. If the goals of instruction are to develop flexible knowledge that transfers to multiple contexts, then instruction and assessments need to measure these aspects. Therefore, a mismatch between learning objectives and assessment methods can be deceptive when measures for routine expertise are used to provide evidence of adaptive expertise.

For example, the literature on engineering and physics education provides one example of how instructional methods can lead to only developing expertise of the routine. For example, in exploring circuits, students learn to be quite fluent at calculating various quantities such as voltage, current and resistance in a circuit (e.g. [4]). In fact, many students can predict what a question will asked based on the picture of the circuit because of their experience solving many text book problems that target specific principles. However, these same students could not reason qualitatively with these principles to compare and contrast how these values will be different. If the students are going to be technicians who troubleshoot existing circuits, the expertise of the routine would be fine. If the students are to become designers of innovative circuits, then they will require a stronger conceptual understanding of these principles.

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EFFICIENCY, INNOVATION, AND IDENTITY

We have been involved in a project to research effective learning environments that develop bioengineering undergraduates capable of applying domain knowledge and engineering skills to solve a range of problems and potentially identify new opportunities for their field. Part of our research has been to review the literature on expertise, metacognition, creativity and identity to define a model of adaptive expertise that informs the design of instruction and assessment. We are finding an important relationship to study is the dependency between experts’ fluent display of knowledge to solve given problems, the characteristics of noticing opportunities for change (creativity) and the motivation to engage in activities that result in innovation. Below is a brief discussion of a model for defining the interaction between these factors.

A commonly observed difference between experts and novices is that experts have years of experience that lead to schemas that helps make their knowledge more routine and implicit [4]. Therefore, experts are able to quickly notice patterns that allow them to efficiently make decision about what to do next [5]. Experts also have deep knowledge structures that allow them to flexibly adapt their knowledge to new situations [3]. Therefore, when they are faced with a novel situation within their domain, then they are able to think about new alternatives. Experts experience and well differentiated knowledge are important to their efficient problem solving abilities for routine activities and their adaptability to solve novel problems within their domain of expertise.

Experts’ also display and ability to leverage what they know to adapt to new problems they have not faced before or to approach new domain areas. This requires an ability to reflect on current knowledge about a situation and identify what more is needed to know to define learning goals that guide a learners inquiry [6]. Metacognitive, or self regulating skills are often discussed free of any specific content area. This is partially because the observed behavior of successful problems can be generalized to specific behaviors, such as, identifying what is unknown; identify how the new situation is similar to an old situation. Often these are generalized to heuristics people can attempt to use as the approach a problem they have not encountered before. However, the study of these self regulating skills and the development of domain knowledge have often been investigated in isolation of each other. Recently the ideas have been explored relative to designing instruction (e.g. [6]), but more still needs to be done to better understand how learners guide their own noticing as they develop more expertise. Once they have developed the expertise and display their ability to reason with this knowledge, then they are closer to displaying adaptive expertise. However, this illustrates the conundrum of bootstrapping the process, which we address later.

The other dimension of expertise is the ability to identify opportunities for change. Part of a person’s ability to see opportunities comes from their deep conceptual knowledge mentioned above. Without a fluent and flexible use of knowledge a person will not be able to identify and expand on that creative idea. Much of the research on creativity has noted experts have a strong command of their domain knowledge in order to define opportunities for change, then take action to make those ideas a reality (e.g. [7]). However, we can not make the assumption that simply having a flexible understanding of the domain knowledge will naturally lead to the generation of innovative ideas. Therefore, what are the mechanisms that lead to creating innovative ideas?

The motivation to seek creative ideas is often displayed by an expert’s willingness to deal with ambiguity and willingness to preserve toward a solution [2]. These could be simple personality traits that a person has developed since they were children. However, another factor that may influence this development is how a person identifies themselves relative to that domain area. We are exploring the relationship between a person’s ability and interest in a domain interacts with their willingness to pursue problems in that domain. From other domain areas such as mathematics, we find that learners can be very competent in their ability and take advanced placement classes for college. However, they do not see themselves as mathematician and have no intention of pursuing careers in that field that require mathematics. Therefore, there identity with the domain is something that they perceive about themselves relative to the domain [8]. This perception may interact with their ability to be innovative in that domain area. Also, we believe this perception can be developed as part of instruction. Therefore, we feel that much of the motivation factors related to displaying adaptive expertise relate to issues of identity.

DISCUSSION

The goals for life long learning and adapting to new situations is a critical component to succeeding in the workplace and in personal affairs. Companies continually make themselves more competitive by refining their products and processes. Therefore, they need employees who can quickly adapt and learn new skills or use new technologies necessary for the company to keep pace with the competition. Companies also need people to identify new opportunities for change that make them more productive and profitable. Also, life skills can be more demanding as more options for goods and services become available. For example, as managers of our personal finances, more decisions need to be made related how to spending money on goods and services, plus planning for the future. Also, with the world changing so rapidly we need to learn to develop a willingness to deal with the uncertainty and be willing to preserve with personal challenges. This development of personal identity can be enhanced with the professional identity. This suggests that our goals for instruction should focus on the development of adaptive expertise in our learners as they prepare for a future that is difficult to predict.

Establishing a goal of adaptive expertise for our educational system suggests the co development of learners’ ability to efficiently apply basic domain knowledge, and develop innovation skills relative that will assist in their
abilities to solve routine problems and identify new problems [9]. One concern of ours is that current instruction may focus too closely on developing expertise of the routine. This is not an unworthy goal, but over emphasizing these skills could lead to instruction that only develops these skills and assessment methods that only measure students’ achievement of these abilities. If instead we seek outcomes that develop learners’ ability to display adaptive expertise, then innovative pedagogical and assessment methods should emerge to meet these needs.

For example, we have been working on a project for enhancing bioengineering education (see [10]). The domains in this field (e.g. biotechnology, imaging, therapeutic and diagnostic optics to name a few) are continually growing and changing on a regular basis. Therefore, if we are to develop bioengineering leaders, then we need to understand how to develop adaptive expertise in our learners. One instructional method that is proving effective is challenge based instruction (CBI). Similar to other inquiry based instruction, our implementation of CBI emulations the engineering inquiry process. Challenges are posed to learners who begin by identify what they know about the problem and what more they need to define in order to solve the challenge. The learner expands on these thought first by comparing them with their peers, then comparing them with experts familiar with aspects of the initial challenge. This activity prepares the learners to research these ideas in more detail with the guidance of the instructor and other independent learning activities. These research activities could be to solve smaller mini challenges. As students study this domain content, they complete various learning activities that assist in helping them test what they know and refine it towards a more formal and operational structure of the domain knowledge.

We think every challenge provides learners with additional contexts in which knowledge can be applied. This helps them develop schemas for the knowledge they need so the knowledge becomes routine. The question asking and reflection on the challenges develops their innovation skills necessary to manage novel problems they will face after graduation, and potentially identify opportunities for new discovers.

Characterizing adaptive expertise has been an important step for our project as we reflect back on our goals and objectives and review how we are achieving and measuring these objectives. We will continue our work to generalize this construct to help inform how learning and instruction can benefit for this construct.

REFERENCES