# What constitutes the “understanding” stage of skill development?

Anderson (1982) asserts that skill learning involves interpreting recently acquired declarative information about how to perform a task into efficient procedural rules that we can observe in expert skill performance. Several reviews of traditional programming-language learning describe this phenomenon of transcending the limitations of declarative programming knowledge as understanding. Anderson et al. (1999) expands the concept of understanding into closely observable learning strategies: direct recall, analogical application of an example, declarative rule formation, and procedural rule formation with practice.

Teaching coding usually starts out by defining the components of the programming language that then have to be practiced and streamlined (Robins et al. 2003). For example, some fundamental items taught to beginners are how to use functions, how to define variables, and how to use different data types and operators. Mayer (1981) examines several strategies as to how this declarative information can be acquired that have implications for teaching and are necessary first steps in skill acquisition. These learners are then assisted in practicing how these items may be combined to produce functioning programs that often involves exposure to new problems. Mayer (1981) draws a distinction between accumulating detailed information of the parts, which Anderson might call declarative knowledge, and understanding. Understanding, according to Mayer (1981), is the ability to manipulate and apply the acquired information towards new problem-solving situations. This suggests a learning trajectory from beginner to expert that is attainable through practice, and also represents an Anderson-like formation of procedural rules from acquired declarative facts. Anderson et al. (1999) further suggest that skill performance is more apparent when learner information is transferred to novel problems and are applied successfully. This aligns with and extends the Mayer (1981) definition of understanding.

According to Anderson et al (1999), learners use different strategies to transfer practiced knowledge to new situations. This was determined in a simple but programming-adjacent problem-solving experiment. Here, subjects form intuitions from explicit examples on how to solve specific problems using a mixture of strategies that vary in levels of efficiency: Learners, rapidly but limitedly, can directly recall responses to problems they have seen before; they can analogically extrapolate a solution by recalling a similar example, which is taxing and inefficient; with practice, they can extract a declarative rule and apply it without referring back to examples; and lastly, with more practice, they can form very efficient procedural rules. The study had observed that a mixture of these strategies was used by learners throughout the experiment sessions. This shows that different avenues maybe taken to arrive at expert performance or understanding.

The progression of skill development is complex and there are often different definitions and hallmarks of what expert performance is across different studies. Anderson et al (1999) sheds some light on this complexity and presents a multi-dimensional view that includes the problem-solving dimension as well as the memory systems that support the learned skill.