Preparation3 Article: Creative Thinking

The Need for Engineers with Creative Thinking

As the world becomes more volatile, uncertain, ambiguous, and complex[1], and with automation expected to spread rapidly to more sectors of the economy[2], the need for more creative problem-solving skills in the workforce has come to the fore.

The need for more creative problem-solvers has been noted in the job market in general[3] and in science, technology, engineering, and mathematics (STEM) professions in particular[4]. On their part, educational organizations have stressed the importance of teaching CPS in science and engineering undergraduate education[5-6].

The most difficult engineering problems have multiple potential solutions and a non-prescribed path to a solution. Solving these problems, which can broadly be called design problems, involves the creation of artifacts which requires creativity[7].

Creativity as a Skill

While no consensus exists regarding the standard definition of creativity, the two components of creativity which are most mentioned are *novelty* and *usefulness*. Novelty has been described by various terms, such as an idea being rare within a particular group[8], "uncommon"[9] (p.478), or unique[10], while usefulness has been defined as utility, "adaptive to reality"[9] (p. 479), effectiveness, or valuability[8,10].

Creativity as a Process

Creativity, and more specifically creative ideation, is characterized by a long period of *incubation*, where the problem is ruminated over in a mostly non-conscious manner. Incubation tends to occupy the longest period in the process of addressing a problem. When successful, the incubation stage is followed by *illumination*, which is the shortest stage of problem-solving. This is the 'eureka' moment where the perception of the problem turns from novel to familiar, and creative ideas arise in the mind of the problem-solver[11].

Creative Ideation Approaches

There are three general approaches for creative ideation[12], all of which involve changing something about the problem representation:

- *Elaboration*: adding new information to the presentation
- *Constraint relaxation*: removing assumed constraints on the representation
- *Re-encoding*: re-interpreting part of the representation

In this course, we will learn and apply two methods for changing the problem representation:

Analogizing (re-encoding): identifying similar problems which have been solved to a satisfactory degree, generating analogies to those problems, and ideating solutions based on those analogies. The problem to be solved is called a target; the problems used to analogize to the target is called a source; and the cognitive operation of analogizing involves abstracting identified relations between the target and the source and applying these relations to the target when generating ideas for solving it[13-15].

Challenging implicit assumptions (constraint relaxation): identifying implicit (trivial, obvious, not stated, not discussed) assumptions about the problem, making them explicit and sharing them, and ideating solutions based on challenging these assumptions[16-17].

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