Seeing the Invisible: A Systematic Approach to Uncovering Hidden Resources

by Tony McCaffrey
Ph.D., Cognitive Psychology
University of Massachusetts Amherst

Abstract

An important aspect of TRIZ problem solving is noticing the resources needed to resolve contradictions. "Resources are things, information, energy, or properties of the materials that are already in or near the environment of the problem" (Rantanen & Domb, 2008). Because of the way we humans process information, however, we tend to overlook many possible resources. The normal processing of our perceptual and semantic systems leads us to notice the typical resources for the problem at hand. The typical is the enemy of innovation; whereas, the atypical, or the obscure, is innovation's friend. But what techniques can help counteract our propensity for the typical and help us uncover the obscure? After devising an extensive taxonomy of possible types of resources, we have created and tested a set of techniques, the *Aha! Toolkit*, that helps uncover the obscure resources. Even though our set of techniques is only a year old, it has already been used to solve several difficult engineering problems. Further, it can assist TRIZ with problems that involve contradictions but will also work with problems involving no contradictions. We present our new cognitive theory of innovation as well as the techniques that help humans see the often-invisible obscure resources.

Introductory Examples

An engineering firm presented us with an unsolved problem: adhere a coating to Teflon. Teflon is a no-stick surface and very aptly named. Immediately, we have a contradiction: stick something to a no-stick surface. The next step is to look for a resource to resolve the contradiction. A possible approach is to ask: What property of Teflon are we overlooking that we can leverage for a solution? If that is too narrow of a scope, we can broaden our search to include the things and types of energy in the problem's environment that might interact with the properties of Teflon to produce the desired effect. *We will present part of our solution to this problem a bit later (because it is proprietary).*

A company challenged us to create a way to detect roadside bombs. If we were to try to articulate a contradiction for this problem, it would most likely be: detect something buried or see something invisible. However, in this case, the contradiction did not significantly help our search. Again, the next step is to look for a resource, either a property of the bomb or something in the environment that might produce the desired effect. *Because our solution is both proprietary and part of a sensitive military problem, we will present only part of our solution a bit later.*

A candle company presented us with a problem they face every few years: create a new type of candle for next year's product line. There is no contradiction in this problem. We are merely trying to create a type of candle that has never been seen before. Again, the next crucial step is to look for a resource that will lead to a working candle that is novel. *We will present one of our many solutions a bit later.*

Regardless of whether there is a contradiction present or not, a necessary step for a solution is to focus on the *resources* needed to solve the problem. If we could systematically search through all the types of *resources*, this would help make problem solving more efficient. In the absence of a methodical search procedure, we are left with an *ad hoc* process where hopefully we eventually stumble upon the key resource needed to solve the problem. Presently, we will develop the various sub-types of *resources* as well as another important category called *interactions* so we can methodically search through them during problem solving.

Obscure Resources and Obscure Interactions

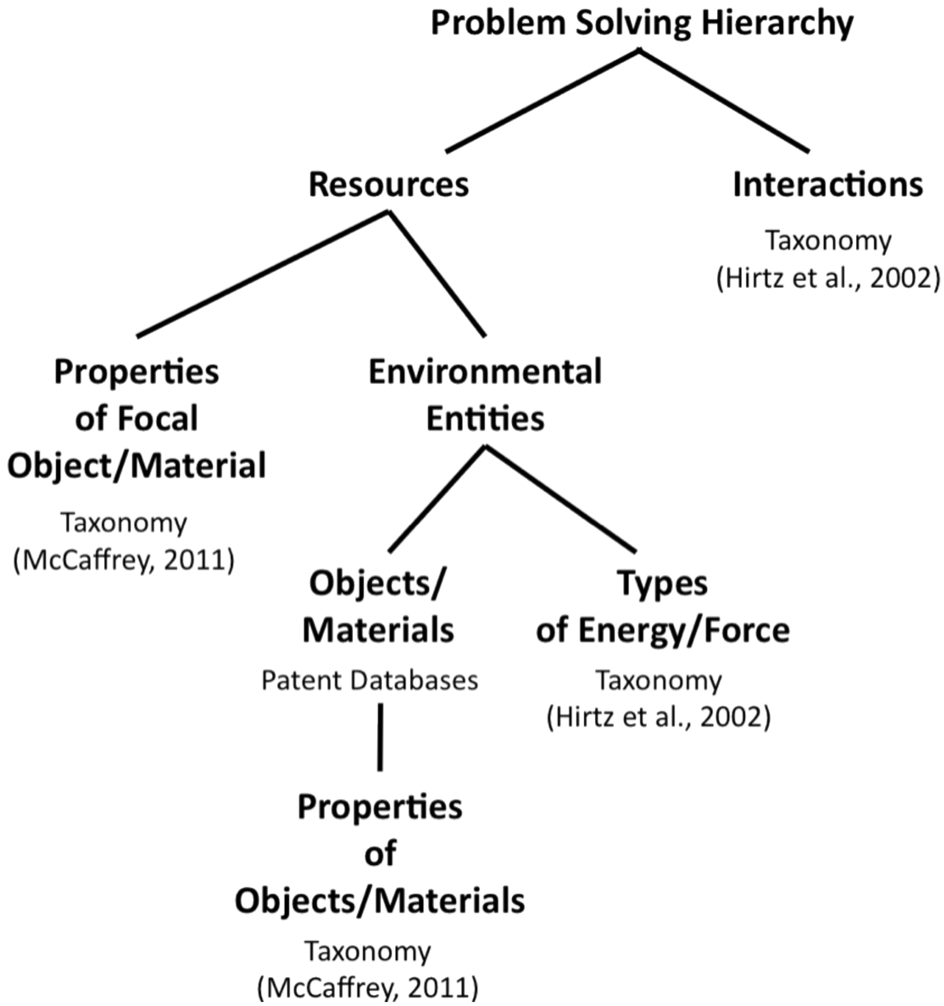
Our new cognitive theory of innovation is based on the common sense observation that if an unsolved problem ultimately has a solution then (1) either people are overlooking something crucial about the problem (i.e., some *resource*), or (2) they are noticing everything necessary except how the noticed things interact to produce a solution. In essence, humans struggle with innovation because we tend to overlook the obscure resources and interactions that innovation requires.

In Figure 1 below, the first level of the hierarchy is composed of *resources* and *interactions*. *Resources* are then sub-divided in various ways found to be helpful in solving real-world engineering problems. Below the types of information in the figure, in smaller print, are the databases that make the methodical searches possible. We will now develop the hierarchy in more detail.

We have found it beneficial to segment *resources* into two categories: the *properties of the focal object/material* currently under consideration (e.g., Teflon or a candle), and the *environmental entities* (i.e., other things in the surrounding environment of the *focal object/material*) that could interact with the *focal object/material* to produce the desired effects. McCaffrey (2011) has created an extensive taxonomy of the properties that an object/material can possess. This taxonomy currently consists of 32 property types. This taxonomy facilitates locating the relevant obscure properties for solving the problem at hand.

The *environmental entities* further subdivide into two types. First, the number of new objects and materials grows regularly. Patent applications for new types of materials and new objects are submitted daily. Each of these new items possesses a unique set of properties that then leads to a unique set of effects that the item can produce in interactions. Each of these new items could potentially interact with our *focal object/material* (e.g., Teflon or a candle) to produce some interesting, if not useful, effects. Patent databases and software that facilitates patent searches, such as *Invention Machine*, are the current methods to efficiently access this information. Further, each *environmental entity* possesses many types of properties that shape how it might contribute to solving a problem. This taxonomy of property types is currently being submitted as part of a software patent application so we will not present it here. However, this taxonomy of property types is articulated in the unpublished dissertation of McCaffrey (2011).

Figure 1: Hierarchy of Resources and Interactions

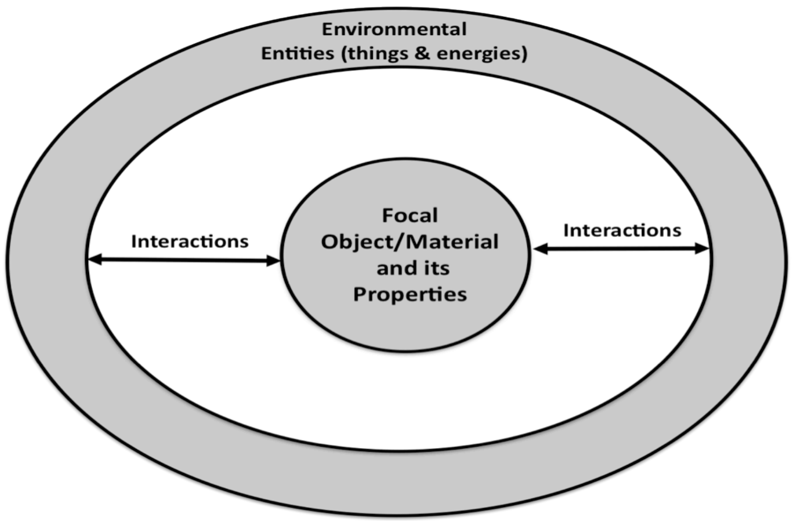


Hirtz et al. (2002) contains a taxonomy of the types of energy (e.g., electrical and magnetic) and force (e.g., gravitational and centrifugal) that might interact with our focal object/material to produce various effects. Hirtz et al. (2002) also contains an extensive taxonomy of the types of *interactions* that any physical entity can be part of.

The taxonomies of McCaffrey (2011) and Hirtz et al. (2002) are an integral part of our *Aha! Toolkit*, which contains a dozen innovation-enhancing techniques that help us overcome our various natural inhibitions to noticing the obscure. The *Aha! Toolkit* helps us search through the space of *resources* and *interactions* in order to uncover the obscure ones needed to solve the problem at hand.

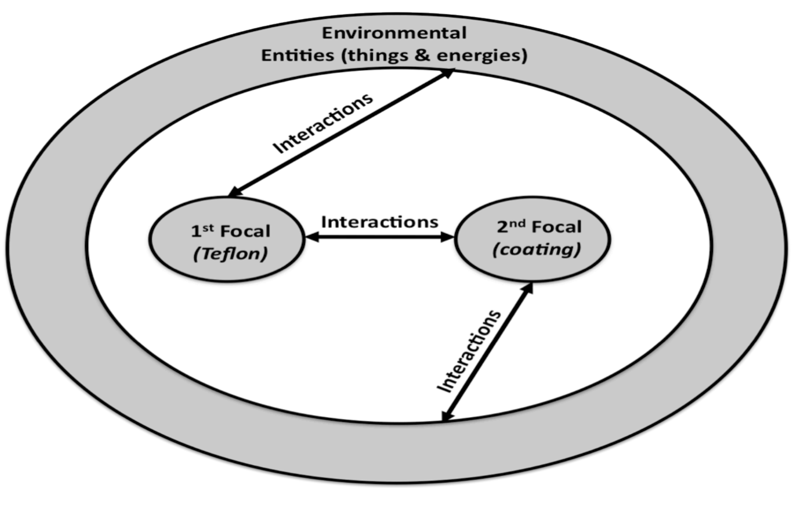
Before using the *Aha! Toolkit* to solve difficult problems, we will briefly present several schematic diagrams that illustrate the basic relations among the *focal objects/materials*, *environmental entities*, and *interactions*. These diagrams present the information in Figure 1 in another way and remind us that when solving a problem we are attempting to craft the proper set of *interactions* among the *focal objects/materials* and the *environmental entities*. First, Figure 2 below shows how, given a single *focal object/material*, the flow of possible *interactions* might proceed. The *environmental entities* are represented as a circle of possible items that surround the *focal object/material.*

Figure 2: Flow of Interactions Given One Focal Object/Material



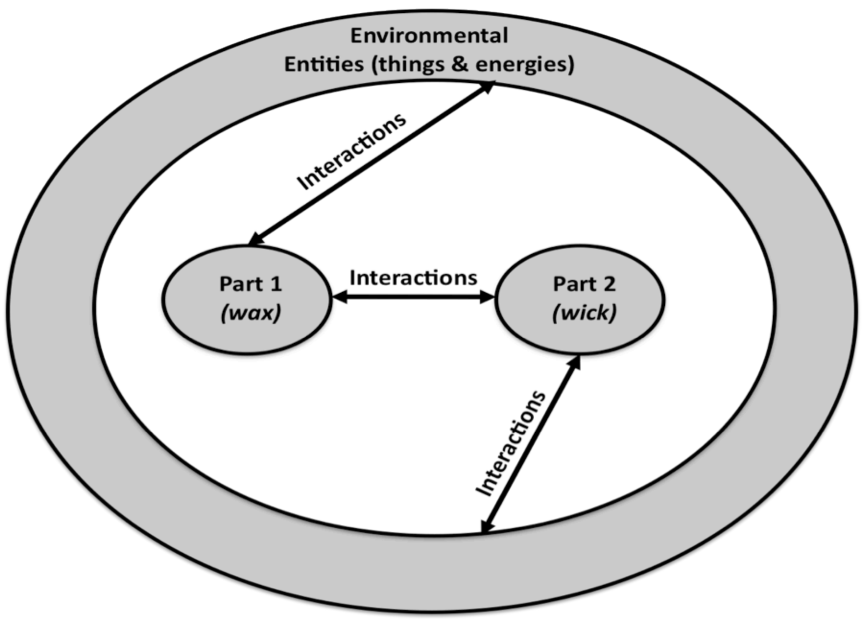
If there are two *focal objects/materials*, such as Teflon and a coating, then we must also consider the possible *interactions* between the two *focal objects/materials*—as illustrated in Figure 3.

Figure 3: Flow of Interactions Given Two Focal Objects/Materials



Finally, Figure 4 shows the possible interaction pattern for a single item possessing multiple parts, as in our example of a candle that is composed of wax and a wick. Notice that the interaction pattern for an object with two parts (Figure 4) is the same as the interaction pattern for two separate objects (Figure 3). In fact, this generalizes so that the interaction pattern for a single object with **n** parts is the same as the pattern for **n** separate items. As we will see below, parts are often overlooked when analyzing the resources for a problem.

Figure 4: Flow of Interactions for a Single Object with Multiple Parts



Solution: Adhering a Coating to Teflon

Because the Teflon solution is proprietary information, we cannot present the full solution. However, we can present the technique that uncovered the obscure resources that then led to a working solution.

The verb used to express the desired goal (e.g., *adhere* a coating to Teflon) contains many hidden assumptions about what we expect in a solution. For example, the verb *adhere* implies using a chemical process to induce one surface to stick to another. By listing and then challenging this assumption, we can consider other ways to induce sticking. Further, *adhere* also assumes (1) direct contact between (2) two surfaces. Again, challenging these assumptions opens up further possibilities. If these and other assumptions remain hidden, then problem solvers are unwittingly channeled to consider only a narrow range of factors when constructing a solution. When we use a particular verb (e.g., *adhere*) to express the goal, we are assuming that the object/material that solves the problem possesses certain properties. By articulating the properties assumed by the verb *adhere* for each of the 32 property types in the taxonomy (McCaffrey, 2011), we can create an extensive list of assumptions hidden behind the verb *adhere*. For each assumption on the list, we can negate it to create an alternative to explore. For example, negating "chemical process" leads us to explore the possible non-chemical processes. Negating "direct contact" opens us to examine indirect contact. Negating "two surfaces" opens up the possibility of using one, three, or more surfaces. In general, for each assumed property ***P*** we unearth, negating the property (**~*P***) unfolds a new space of options for us to consider. In the case of the Teflon problem, the process of unearthing and then negating hidden assumptions very quickly led to a workable solution. The presenting engineering firm has judged that our solution has a high probability of working.

In sum, the verb we choose to express our goal can severely restrict us to a small range of the possible solutions. Becoming aware of the many assumptions underlying our choice of verb can open us to an incredibly large space of possible solutions that were invisible to us just moments before.

Note that this *Goal Verb Technique* does not solve the problem for engineers but merely unearths obscure properties whose negations can open up promising new possibilities to consider. The human engineer is needed to craft potential solutions based on the newly noticed properties. In fact, all of the techniques from the *Aha! Toolkit* focus on uncovering either obscure resources or interactions. The reason different techniques are required is that there are many psychological reasons why we overlook various resources and interactions. In the case of the *Goal Verb Technique*, we simply are often unaware that the particular verb we use to express the goal is riddled with constraining assumptions that greatly restrict the types of solutions we are able to consider.

Computer Assistance for the Goal Verb Technique

Hirtz et al. (2002) lists the possible *interactions* for a physical object by stating that all engineering goals and operations can be described by any one of approximately 120 verbs. This collection of verbs is represented as a hierarchy starting with eight general verbs (*branch, channel, connect, control, convert, provision, signal, and support*) that branches into levels of more specific verbs as the hierarchy deepens. For all verbs in the hierarchy, using the taxonomy of McCaffrey (2011) we can articulate the assumed properties for each verb and embed them in software that we call the *Innovation Assistant* (IA). When solving a problem, users of the IA software can systematically examine the rich set of assumed properties for the verb they used to describe their goal. Questioning and negating the assumed properties leads to a rich exploration of new possible solution options. Further, rewording the goal by changing the verb changes the assumptions. For example, while the verb *adhere* has an association with a chemical process, the verbs *fasten* and *connect* do not. Our IA software navigates through the varying assumptions of the various verbs used to express the goal. The result is the unearthing of many assumptions made unknowingly that blind us from considering many factors while searching for a solution.

Solution: Detecting Roadside Bombs

A company challenged us to create an idea to detect roadside bombs. The expressed contradiction—detect something buried or see something invisible—does not really help us to direct our search. Proposed solutions to this problem currently focus on either detecting the bomb itself through its metal or disrupting the electronics of the bomb. After inspecting the property type taxonomy (McCaffrey, 2011), we shifted our focus from the bomb's physical make-up to the events that the bomb is involved in (e.g., building the bomb, transporting the bomb, burying the bomb, and detonating the bomb). This approach led to an idea for a mechanical method that could reliably detect the displacement of the dirt above a buried bomb rather than trying to detect the bomb itself. No further information can be disclosed at this time due to this solution being proprietary information as well as being part of an ongoing open military problem. Again, the property type taxonomy did its job by helping us move from the commonly noticed properties to an obscure property.

One Solution: A New Candle Design

Because innovation rises out of the obscure, to create new candle designs for next season, we analyzed which of a candle's properties are commonly noticed and which are infrequently noticed.

Figure 5: Which Properties of a Candle are Commonly Noticed?

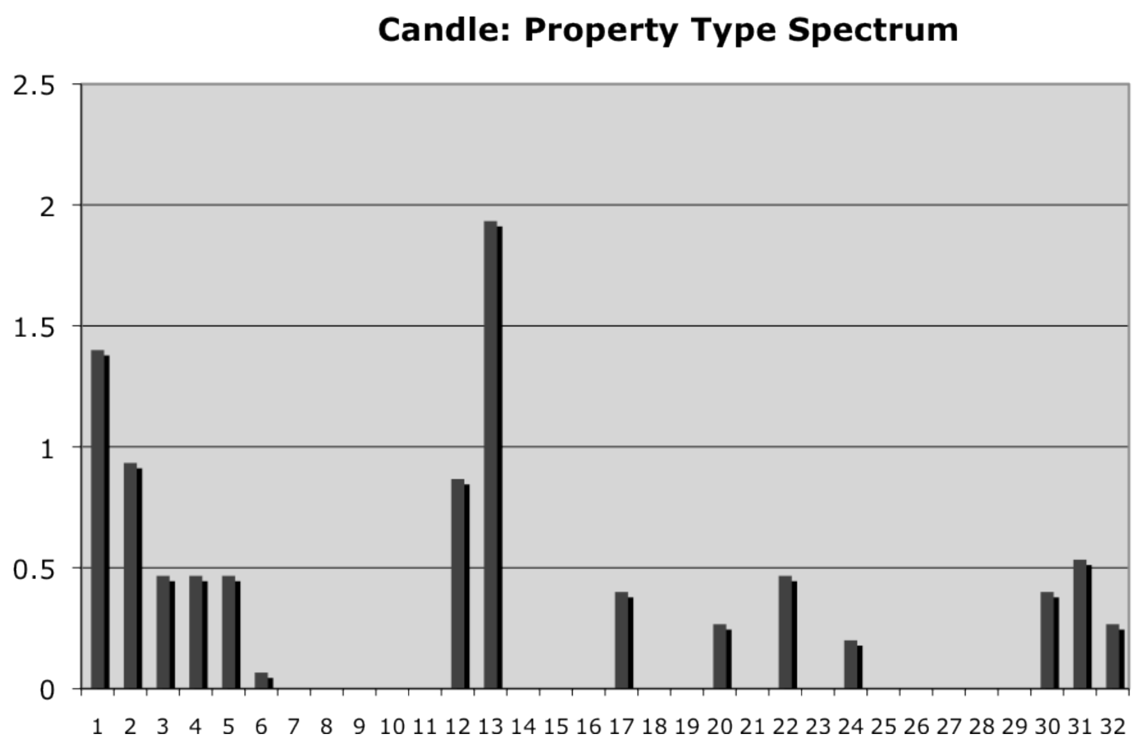


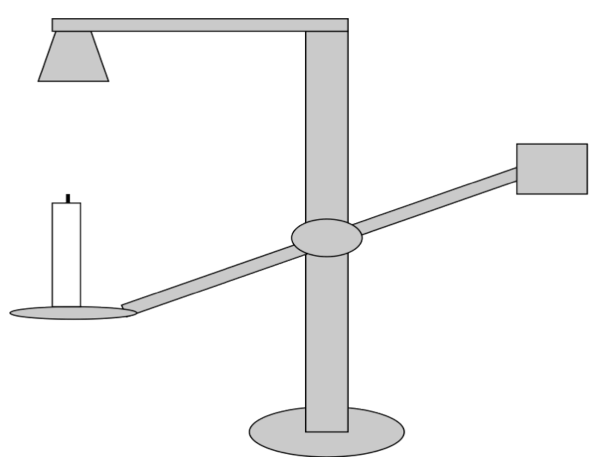
Figure 5 shows the results of a survey of 96 people who were given 4 minutes to write down as many properties, features, and associations for a candle as they could. Using the taxonomy of McCaffrey (2011), we classified their answers among the 32 property types of our taxonomy. The y-axis of the graph represents the average number of times these subjects listed a property of a particular type. The x-axis shows the 32 property types presented by number. Again, because a patent application is currently being prepared for the software that implements searches on this taxonomy, we are not currently at liberty to disclose the 32 categories of the taxonomy. Regardless, the overall shape of Figure 5 makes it clear that some types of properties are commonly noticed (e.g., properties #12 and #13) while many properties are infrequently or never noticed. The infrequently or never noticed properties (i.e., the obscure ones) are the exact properties upon which to build new candle designs.

For example, in our survey, not a single person mentioned anything about the motion (property #28) of a candle (e.g., "candles are motionless when they burn") or anything about the weight (property #9) of a candle (e.g., "candles lose weight when they burn"). Combining these two overlooked properties, we created a candle that moves by itself based on its weight loss as it burns.

As Figure 6 shows, the candle is placed on one side and is counterbalanced by a weight on the other side. As it burns, it loses weight and slowly rises. Just for fun, we put a snuffer at the top so the candle would eventually snuff itself out. The novelty of this design has been verified by two candle companies: *Yankee Candle* and *Pilgrim Candle*. After we make the overall structure of Figure 6 look ornate, we will have created an attractive new design to sell called the *Self-Snuffer*. Using our *Property Spectrum Technique* (see Figure 5) for a candle, we created eight new designs that have been verified to be novel.

Note again that the *Property Spectrum Technique* of Figure 5 does not design the new types of candles. It merely helps us notice the obscure properties of a candle that new designs can be based upon. A human is required to craft the obscure properties into actual new designs.

Figure 6: A Self-Snuffing Candle



Summary

Amidst all the proprietary information that we had to withhold from our various examples, we have tried to portray an approach to problem solving based on the observation that if an unsolved problem has a solution, then either people have been overlooking a resource or interaction (or both) that is necessary to solve the problem. The presence of extensive taxonomies for the various types of resources and interactions helps make it possible to transform innovation from an *ad hoc* process of accidentally stumbling upon the key resource/interaction to one of systematically searching through the space of possible resources/interactions. Embedding these taxonomies in search-friendly software makes the search process even more efficient.

Articulating the contradiction of a problem is not always possible and not always helpful. First, not all difficult problems are based on contradictions. Creating a new type of candle is difficult but does not involve a contradiction. Second, from our vantage point, articulating a contradiction (if it exists) is just one way to help narrow the search for the resource/interaction that is needed to solve the problem—but it is not always the best way. The contradiction underlying detecting roadside bombs did not help us narrow our search in any significant way. Further, in the Teflon problem, articulating the contradiction that we need to stick something to a non-stick surface does not necessarily guide us in how to resolve it. On the other hand, uncovering the implicit assumptions of the verb *adhere* was very effective in that it allowed us to challenge these many assumptions and then move beyond them to the resources/interactions required for a solution.

In sum, all unsolved problems require noticing some overlooked resource or interaction. Sometimes articulating a contradiction of the problem (if it exists) can help draw attention to the needed resources/interactions. Other times, however, it is not clear how to move from the contradiction to the proper resources/interactions. The *Aha! Toolkit* contains many techniques to uncover the obscure elements of the various taxonomies that are relevant to the problem at hand. In its short existence, the *Aha! Toolkit* has been shown to be effective in solving several difficult engineering problems (McCaffrey & Spector, 2011). Embedding the toolkit in software will make using the *Aha! Toolkit* even more efficient as the software helps optimize the searches of the various taxonomies.

References

Hirtz, J., Stone, R., McAdams, D., Szykman, S. and Wood, K. (2002). A Functional Basis for Engineering Design: Reconciling and Evolving Previous Efforts, *Research in Engineering Design*, Vol. 13(2), 65-82.

McCaffrey, A. J. (2011). The obscure features hypothesis for innovation: One key to improving human innovation. Unpublished doctoral dissertation, University of Massachusetts Amherst.

McCaffrey, A. J. & Spector, L. (2011). How the *Obscure Features Hypothesis* leads to *Innovation Assistant* software," *Proceedings of the Second International Conference on Computational Creativity*, 120-122.

Rantanen, K., & Domb, E. (2008). *Simplified TRIZ: New Problem Solving Applications for Engineers and Manufacturing Professionals*. New York: Auerbach Publications.