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Rethinking Technology & Creativity in the 21st Century

Abstracting as a Trans-disciplinary Habit of Mind

by Danah Henriksen, Chris Fanhoe, Punya Mishra, & the Deep-Play Research Group*, Michigan State University

"Beware lest you lose the substance by grasping at the shadow."
– Aesop

*"Abstraction is real, probably more real than nature.
I prefer to see with closed eyes."*
– Joseph Albers

"Abstraction is one of the greatest visionary tools ever invented by human beings to imagine, decipher, and depict the world."
– Jerry Saltz

We have previously described seven "tools for thinking" that are part of trans-disciplinary thinking and creativity: Perceiving, Patterning, Abstracting, Embodied Thinking, Modeling, Play, and Synthesizing (Mishra, Koehler & Henriksen, 2011). The last two articles in this series focused on the skills of Perceiving and Patterning, respectively. This article highlights the third trans-disciplinary habit of mind: Abstracting. In our conceptualization, this involves a multisensory approach, emphasizing analysis of the domain and seeking analogies across domains, to discover the core essence of some phenomena or object of study.

It is common practice at the end of an interview, to ask an applicant to engage in a seemingly simple task – to describe themselves in three words. There are of course variations of this, where the interviewee must identify their greatest strengths, or summarize why they would be the best candidate for a position. This type of question forces one to go beyond the details of the resume, the layers of experience or the history of accomplishments, to capture *the core* of what defines a person, and what they may have to offer. Each candidate's response may be similar in concept, but almost certainly unique in the details and substance of how they encapsulate themselves. This essence may not remain static across time, since one's response may vary depending on the context, or recent developments in life. That said, abstracting the key elements from your personality, accomplishments, education and potential (boiling all the details down to a set of fundamentals) may provide the interviewers with the insight they need to hire you.

In a more general sense, the mental skill of abstraction can yield new insights about an idea, an individual, a thing, or a process, because it involves cutting to the core essence by stripping away details not essential to the task at hand. Abstraction can allow us to forge deeper connections and understandings, through a process of analysis as well as through making analogies to other

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areas. We explore these further in the sections below.

Experiencing the Abstract

Abstraction is a process of revealing a critical essence of some real object that exists by removing everything except a finite number (often just one) of its key elements. To identify a key element, one must focus on one specific area or feature of the object relevant to the current task (Mishra, Koehler & Henriksen, 2011). Abstracting allows us to consider these core elements or properties of the object, not just by looking at it but also through a multisensory approach with “all the wealth of sensations that we experience” in the real world (Root-Bernstein, 2001). In order to truly understand a thing and “abstract out” its core properties – the essence of it, or its fundamental nature – you must examine all of its different properties and nuances, by experiencing the object using different senses and engaging in a process of analysis that questions these properties and their relevance to the goal being pursued.

For example, simply looking at an orange may provide information about its shape, color and size. However this would miss the insights that could be gained through feeling the texture, tasting the juice, cutting through the skin or smelling the fruit. Such additional insights allow you abstract to the “orange-ness” of an orange (not just in terms of color, but in the *essence* what makes it an orange). This multisensory interaction brings out unique meanings, and can lead to different impressions and new understandings of its essential nature. This process often takes time, as it requires careful observation and sustained engagement with the subject – which is part of the “perceiving” skill discussed in a prior column (Henriksen, Mehta, Mishra & the Deep-Play Research Group, 2014).

At this level, the process of abstraction remains a relatively isolated activity. To abstract out the core ideas, you strip away extraneous details and define the essence of a thing. But there is another aspect to the skill of abstraction, which helps to build con-

nections for deeper understanding and new and creative thinking. This is the process of analogizing, which is often central to abstraction. Mishra et al. (2011) highlight this aspect of the skill as, the “finding of analogies between seemingly disparate things.” So in this sense abstraction is a multilayered skill, involving the ability to focus on one key feature of a thing, as well as the ability to think in analogies to foster deeper understandings, connections and creative thinking.

“Abstracting is Just Like”... Categories and Analogies

Through focus and observation, the essence of an object, process, person or a thing can be revealed and identified. After this fundamental nature is recognized, we can start to look across seemingly different objects or processes for similarities or differences, and through the process of comparison and contrast begin to build analogies that help us to better understand the object under scrutiny. Finding connections between objects moves beyond an identification phase and into developing new possibilities for how we see objects and their relation to another. Hofstadter & Sander (2013) discuss the fact that once connections are developed through categorization, they can also be grouped based on a set of differentiating properties or attributes. In fact, in their recent book, *Surfaces and Essences*, Hofstadter and Sander argue that analogy lies at the “core of all thinking.” They emphasize the importance and value of analogical thinking, suggesting that the only way we can understand new phenomena is by making an analogy to something we have experienced in the past. The only way we can grasp the new is by *seeing one thing in terms of another*.

This leads us to groups of ideas with common themes or unique differences based on distinct characteristics. Whether we identify similarities or differences, this technique of categorizing, comparing and contrasting, can often bring us to a new understanding. This process of analogizing helps us to “see” things in new ways, and better understand them through connection.

For example, a categorization of things based on “strength” may contain such objects as a tank, a gorilla, and tungsten. Thinking about the items in these categories may provide new insight about how they are connected, structured or designed through comparing and contrasting (Root-Bernstein, 2013). The obvious surface differences between a tank, a gorilla, and tungsten fade away as we focus on this new, shared aspect of their nature.

Analogies in Disciplines and Human Cognition

Hofstadter and Sander’s (2013) argument that analogies are the basis of human cognition arises from the field of linguistics. Linguists have noted how the essence of communication, or language itself, is abstract in nature (Chomsky, 1968). Language is a system of connection between two disparate things – i.e. signs/symbols and the “things” that they describe – which help us communicate with others and share meanings and thought. This act of relating different things, to better understand and explain them, *is* a process of abstraction, and thus a crucial part of our mental life.

In a similar vein, the Root-Bernsteins (1999) have noted that the basis of all art is abstraction (to communicate an idea or an impression through a piece of visual work). But art is not alone as a field for abstract thinking. For instance – what is mathematics if not a universal language based on abstract thought? It is a system of signs and symbols that requires abstraction (and logic) to describe quantities, measures, calculations, phenomena, and more. And by that token the sciences are inherently abstract, not only because they use mathematical/scientific language, but also because science involves the relational aspects of different phenomena, organisms, particles, or natural objects and events. It requires us to make connections, and as mentioned before, *explain one thing in terms of another* (Gentner & Jezior-ski, 1993). In fact, Nersessian (1984) and Tweney (1983) have suggested that analogy and metaphor are at the core of scientific thinking.

Abstracting in Action

Hofstadter and Sander (2013) suggest that abstraction connects to our everyday life experiences, but the authors also highlight dozens of advancements in science and art based on analogous thinking. In the way that analogies help us to see through and beyond categories, they provide a deeper and comprehensive understanding of a thing by making connections.

Artists regularly engage in abstraction. For instance, consider Picasso's famous "Bull's Head", a found object artwork, in which Picasso saw the shape and figure of a bull's head clearly, within the lines and shape of an old bicycle seat (see <http://bit.ly/1n1C72W> to view the actual artwork). The analogy lies in shape and form, and Picasso noted that the piece requires the viewer to see both the bicycle and the bull, in order for the piece to be complete and impactful. In other words, the bull shape informs the lines of the bicycle seat and vice versa.

The cartoons of Saul Steinberg, of *The New Yorker*, are another excellent example of abstraction in art and culture. His most famous cartoon, "View of the World from 9th Avenue", shows the world laid out from 9th Avenue, with a bit of 10th Avenue behind it, a small portion of America beyond it, then the rest of the world barely registers beyond this depicted as a series of small islands (noted as Russia, China, Japan, and so on). Within this single visual, the larger and more complex notion of American parochialism that ignores other cultures is revealed, without a need for detailed explanation. Or we might look to Steinberg's drawing of a cocktail party, in which guests are depicted in different artistic styles – from Pointillist, to Impressionist, to Cubist, etc. – to demonstrate an analogy between art idioms and psychological types. Consider also his "passport photo" created just from his fingerprints (<http://bit.ly/1nYaDeZ>). This image captures at multiple levels the meaning of identity and how it is represented. These are just a few examples, which abound in the world

of art, where there is no shortage of abstract thinking.

But analogy goes far beyond this. It can be seen in scientific analogous thinking across a range of situations. Niels Bohr's model of the atom, which made an analogy between the atom and the solar system, is a classic example. Bohr's model built on a previous model by Rutherford, but a crucial aspect of his explanation focused on comparisons to the solar system. His analogy showed how electrons revolve around the nucleus like planets revolving around the sun. However, instead of gravity being the force of attraction, electrostatic forces keep the electrons in orbit.

Or in another case, Newton's analogy, comparing the moon to a cannonball propelled with enough velocity that it passes into orbit, is a scientific analogy that ultimately led him to his Theory of Universal Gravitation. These examples had major effects on their scientific fields, yet they are just a couple, out of many and varied illustrations of effective analogous thinking. In each of these cases, creativity emerged from drawing seemingly hidden connections and new applications based on conclusions drawn about an object's essence from information revealed at the surface. Such creative analogies continue to impact the areas of science and technology today.

The field of bio-design is a continually developing field that has significantly changed the landscape of science, transportation and medicine. Designers and scientists often look to nature for inspiration, simplicity and beauty to try and better understand how our world works. After intense study and contemplation, leaps of creativity are possible based on drawing connections (analogizing) and seeing possibilities between nature's activities and the ideal vision. For example, seeing insects scoot across the top of the water without falling into it is a phenomenon that has been observed for centuries and fosters a discussion about weight and surface tension. However, watching a heavier basilisk lizard effortlessly skim across the water is a different phenomenon entirely

due to the added weight. After studying the mechanics of the lizard motion, researchers understood that it was about the shape and size of its feet, along with the precise angle in which the lizard propels itself forward. This understanding has led to designs for biomimetic robots that can be used for improved water safety/rescue operation (Floyd, Keegan & Sitti 2006).

Another example, from Professor Frank Fish from West Chester University, seeks to transform energy efficiency through the application of knowledge about humpback whale flippers. His exploration revealed that the bumps on front edge of the humpback whale flippers do not cause drag, as existing principles of hydrodynamics predicted – instead these bumps made the whales even more aerodynamic (Fish, Weber, Murray & Howle, 1995). He then abstracted out this idea, and applied this understanding, called the "tubercle effect", to wings and fan blades to increase the efficiency and output. These leaps in design and understanding range from the commonplace to the transformational, but are always fueled by a deep study of the core components of a thing, to make new connections that can solve real world problems.

Abstracting and Creativity

The skill of abstracting involves both identifying the core essence of an object, as well as the ability to draw connections through analogies – and this begs the question of where this process can lead? Simply connecting meanings and drawing mundane analogies help us make sense of our place in the world, and allows us to accomplish our routine tasks and responsibilities in life. But at a broader level, abstracting can also assist in creative problem solving and help us to seek out alternatives or new approaches. This type of productive creativity is an essential component of 21st century thinking, in being able to offer solutions, modify designs and come up with different approaches to address complex issues.

In Mishra, Henriksen and the Deep-Play Research Group (2013),

we offered a definition of creativity as being NEW: novel, effective and whole. In this model, the creative process yields things that are “not just **new** or interesting, they are useful or **effective**, and they have a certain aesthetic sensibility, which is tied to their specific context—the **whole!**” Creative work is often viewed through the perspective of generating NEW products (ideas, objects, processes, etc., that are novel, effective and whole). Abstraction and analogous thinking drive creative acts, and the process of connecting objects, attributes and concepts becomes a method for stimulating NEW approaches and designs.

Abstraction involves thinking deeply about an object to discover its fundamental nature, and to make comparisons for understanding, and find connections to other objects, ideas, or things. The connections revealed may be used for enhanced design, new breakthroughs, and fresh innovation, and it is this process that leads to creative production across domains.

Abstracting in Education

So how does a student or teacher leverage abstracting to engage in creative thinking and design? First, adequate time must be designated to the task of abstracting the essence of an object. The process can be time intensive, as it requires examining multiple viewpoints required to peel away the unnecessary components. A multisensory approach is also critical—seeing the object from diverse sensory perspectives offers us new ways of identifying the essence. Prior knowledge and context are significant contributors to the development of abstractions and must be valued as reasons for different perspectives about the same object. Categorization and analogous thinking are also essential in order to compare, connect and extend the various essences identified. Once these relationships are defined and considered, novel, effective and whole solutions can emerge.

In the field of teaching, one of the most critical tools that an educator has for helping a student to think in

abstraction, and to better understand a complex idea, is the tool of analogy. Abstraction can be rather abstract (pardon our recursiveness), and students don't always immediately or instinctively understand how to cut to the core or get to the essence of a thing. Thereby, analogy can often be the easiest entry point into beginning to think in abstraction.

Gentner and Jeziorski (1993) have noted how in processing analogies, people innately hone in on particular types of similarities and ignore others. So for example, they suggest that a student seeing the analogy “a cell is like a factory” is unlikely to assume that cells are literal buildings made of brick and mortar. Instead most people can figure out that, like a factory, a cell has materials coming in to aid the process of production. It is this emphasis on common relational tendencies that makes analogous thinking so illuminating (Gentner & Jeziorski, 1993) – and is a valuable way for teachers to help students get access to abstraction.

Examples of Abstraction in Education

In our Master of Arts in Educational Technology program at Michigan State University we have a course focused on creativity in teaching in which the students (who are also classroom teachers teaching a variety of different subject matters, topics, and age levels) work on developing lessons or pedagogical ideas based on the seven trans-disciplinary thinking skills. In the previous articles in this series (Henriksen, Mehta, Mishra & the Deep-Play Research Group, 2014; Henriksen, Cain, Mishra, & the Deep-Play Research Group, in press) we noted a few examples of how the first two skills (of perceiving and patterning) can be employed in teaching settings. Here, we offer two examples based on the skill of abstracting, and how this has been effectively used in the work our teachers do in their courses.

In the first example, a high school art teacher focused her project on the topic of batik (an ancient, traditional Indonesian art form, in which fab-

ric is intricately dyed and decorated, through a process involving wax and dye). This teacher typically spent some time lecturing to her students about the cultural implications of batik, before entering into the artwork/craft lesson on batik. In this case however, she designed a short activity in which they would make a brief film, to abstract out the bigger idea of what batik is about culturally. To exemplify this for her lesson design, she created such a short movie herself, to abstract the core of this unique art form. Her film was a 30 second slideshow that emphasized the simple, central premise that “batik is life” – with images that focused on the many cultural and life contexts in which batik is central to life in Java, Indonesia. She noted that,

Abstraction provides a unique tool to closely consider batik's position as art, craft, livelihood, social indicator and celebratory flag... I felt a movie that focused on the physical characteristics would have eliminated the most vital element – the function of batik in the everyday lives of Indonesians. My abstraction (in the form of a short film) focuses on the variety of ways batik is used in society, including status, wedding celebrations, welcoming new babies, and burying the dead.

So, this art teacher was able to use abstraction in an activity that helped her cut to the core of what the topic of batik is really about – cultural life. Design elements, and skills/techniques can be learned in the action of working on batik, but this abstraction through a short movie helped hone in on cultural relevance.

In another example, a science teacher focused on abstraction with the concept of heat transfer. Her idea was to create a concrete poem that in its words and typographical layout maps onto some key characteristics of the science underlying heat transfer. Her poem is shown in the image above.

She described how this visual

Heat is some thing that spreads with speed that is quite dramatic
 Over all objects and through vacuum the movement is quite bOLD
 There is something though that seems to be quite ironic
 How the air in convection seems to just fold and unfold
 Over and over it tumbles in patterns that just look artistic
 Truly masking the fierce heat transfer in a sight to behold

Figure 1. A concrete poem.

analogy helped to give a better sense of the essence of the idea, as such,

Heat transfer can be the shape of the air movement and the different directions in it. I made an analogy between the invisible directions of air movement and visible letter spreading (which is happening between two different temperatures.) As a result, the shape and the color of the poetry provide us with an image to reveal an aspect of the invisible phenomena of heat transfer.

Note as well the richness of the poem—where it constructs an analogy both in its choice of words *as well* their layout to scientific ideas (a great example of the integration of form, function and meaning). Moreover, the poem is also a complex acrostic where the first letter of each line repeats the word *HOT*, and the last letters spell out the word *COLD* (each of course represented by red and blue colors!).

In this course on creativity for teachers, our students do teaching projects based on trans-disciplinary skills across a range of subjects. Although the two we have briefly noted here focus on science and art, it is clear that abstraction is a skill that has relevance and value for exceptional thinkers in many different disciplines. Analogy may be one of the clearest and most relatable entry points for utilizing this skill – but in any way it is employed abstraction is always about cutting to the core, the essential nature, of a thing, to help us better understand it. This skill has the potential to illuminate one object, idea, or thing (often in terms of another known quantity), which makes it valuable for true comprehension, as opposed to just knowing facts. When we get students to this place of genuine understanding, where they are able to cut to the essence of what is really im-

portant, then this is the place where meaningful creative acts take place.

We end with an example from the poem *Design* by Robert Frost, which demonstrates how abstraction/analogy can convey a complex idea in a very simple but real and relatable manner. In this poem Frost describes an everyday scene in nature, where a spider on a flower is holding a moth captured as its prey. But Frost’s description uses deathly metaphors to imbibe this scene with a sense of evil purpose. The scene sounds cold and malevolent, to suggest that the larger design of nature must then, by extension, be cruel and wicked. Then, the final lines reveal a critical question:

*What brought the kindred
 spider to that height,
 Then steered the white moth
 thither in the night?
 What but design of darkness
 to appall? --
 If design govern in
 a thing so small.*

With this brief and simple analogy, Frost forces the reader to confront beliefs about purposeful (“God-given”) design in nature. Through analogy, Frost creatively and succinctly makes us consider profound questions related to the meaning of life and the important role that is played by chance, in how it unfolds. Frost constructs a stark comparison between the beauty of the scene and the random nature of the gruesome encounter occurring within it. Through this he manages to ponder the bigger question of whether a larger design is at work, or whether our lives and universe are happenstance. The use of small and explicit connections to make a larger, more implicit point reveals a fragment of the greater power of analogy and abstraction. And who better than a poet to reveal this?

References

- Fish, F. E., Weber, P. W., Murray, M. M., and Howle, L. E. (2011). The humpback whale’s flipper: Application of bio-inspired tubercle technology. *Integrative and Comparative Biology*, 51, 203-213.
- Floyd, S., Keegan, T., & Sitti, M. (2006) A Novel Water Running Robot Inspired by Basilisk Lizards. *Proc. of the IEEE/RSJ Intelligent Robot Systems Conference*, pp. 5430-36, Beijing, China, Nov. 2006.
- Gentner, D. (1983). Structure mapping: A theoretical framework for analogy. *Cognitive Science*, 7, 155-170.
- Gentner, D., Jeziorski, M. (1993). The shift from metaphor to analogy in western science. In A. Ortony (Ed.), *Metaphor and Thought (2nd ed)* (pp. 447-480). Cambridge, England: Cambridge University Press.
- Henriksen, D., Cain, W., Mishra, P., & the Deep-Play Research Group. (in press). Making sense of what you see: Patterning as a trans-disciplinary habit of mind. *Tech Trends*.
- Henriksen, D., Mehta, R. Mishra, P. & the Deep-Play Research Group. (2014). Learning to see: Perceiving as a trans-disciplinary habit of mind. *Tech Trends*, (58)4, P. 9-12.
- Henriksen, D., Mishra, P., & the Deep-Play Research Group (2014). Twisting knobs and connecting things. *Tech Trends*, 58(1), 15-19.
- Hofstadter, D. & Sander, E. (2013). *Surfaces and essences: Analogy as the fuel and fire for thinking*. New York: Basic Books.
- Mishra, P., Henriksen, D., & The Deep-Play Research Group (2013). A NEW approach to defining and measuring creativity. *Tech Trends*, 57(5), 5-13.
- Mishra, P., Henriksen, D. & The Deep-Play Research Group (2012). Rethinking Technology & Creativity in the 21st Century: On being (in)disciplined. *Tech Trends* 56(6), 18-21.
- Mishra, P., Koehler, M.J., & Henriksen, D. (2011). The Seven Trans-Disciplinary Habits of Mind: Extending the TPACK Framework Towards 21st Century learning. *Educational Technology*, 51(2), 22-28.
- Nagai, Y. & Taura, T. (2009) Design motifs: Abstraction driven creativity - A paradigm for an ideal design-, *What is “What’s the Design”?* *Special Issue of Japanese Society for the Science of Design*, 16(2), 13- 20.
- Root-Bernstein, M. (2001). Abstracting Bulls: A Dancing Words/Writing Dance Workshop. *Journal of Dance Education*, 1(4), 134–141.
- Root-Bernstein, R. S., & Root-Bernstein, M. M. (1999). *Sparks of genius: The thirteen thinking tools of the world’s most creative people*. New York: Houghton Mifflin.
- Ward, T.B., Patterson, M.J., & Sifonis, C. (2004). The role of specificity and abstraction in creative idea generation. *Creativity Research Journal*, 16(1), 1-9.

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