The Psychological Process Of Discovery

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Discovery is not merely an act; it is a *process*. The boundaries between the rational and the irrational are unmarked, and it can be very difficult to use reason to distinguish between the two, yet they both play a role in the psychological process of discovery. With his discovery of three important astronomical laws[1], German scientist Johannes Kepler (1571–1630) provided great support for the Copernican view of a sun-centered solar system. During his many years of research, Kepler didn't always recognize what was rational and what was irrational, and the mixing of the two in his belief system affected his productivity. Arthur Koestler's written accounts of Kepler's life show the scientist not only to have repeatedly mixed the rational with the irrational, but also to have frequently been beleaguered by hardships. That the process of discovery is difficult is almost surely a certainty. The psychological aspect of the process of discovery was complicated for Kepler, and is still such for discoverers in countless fields of endeavor. It is a process requiring open-mindedness, rigor, discipline, and should welcome a harmonious relationship between faith and reason.

Since about the mid 1400s, there has been an increasing separation between scientific and non-scientific disciplines. Our modern science today took centuries to develop into the critical structure we now recognize as the scientific method. At the period of time around the Renaissance, much of science was ingrained with religious dogma. We now understand that combinations of rational and non-rational thinking made up the beginnings of our modern science.

Kepler believed that the geometrical shape of the sphere was a symbol of the Holy

[1] First Law (The Law of Elipses): planets move around the sun in ellipses, with the center of the Sun being located at one focus; Second Law: (The Law of Equal Areas): An imaginary line connecting the center of the Sun to the center of a planet sweeps equal areas in equal times; Third Law: (The Law of Harmonies): The ratio of the squares of the orbital periods of two planets is equal to the ratio of the cubes of their semi-major axes.

Trinity. He recognized that there were five perfect solids[2] that could fit into a sphere, and he tried to prove that the planetary orbits within our solar system were contained within their shapes. Kepler held onto this irrational belief that the planets should conform to a divine structure for too long, even after acquired evidence was non-conforming. He also believed strongly in astrology and thought that various positions of planets affected the human psyche. These metaphysical ideas were ingrained in his belief system. At times, Kepler's faulty assumptions were intentionally overlooked as he proceeded for extended periods on an erroneous path. The problem with holding onto an irrational belief is that incorrect data is sometimes ignored or explained away so as to fit with the theory. Eventually, Kepler succeeded in understanding planetary orbits, but the path of discovery was a rocky road indeed. It was an unmarked road with numerous switchbacks, dead ends, wrong turns and crossroads.

Like a great explorer, Kepler had to create his own way, and received very little help from others. Even colleagues with different beliefs and values were of little help to him. For example, when he started to integrate physics into his study of astronomy, his prior teacher, Michael Maestlin, didn't think that the two disciplines should be integrated. Old beliefs tend to linger and they hinder progress. But their role, even if irrational, is that they eventually provide for a contrast with which to ascertain truth through the use of reason and rationality.

According to Whitehead, reason wants to clarify some method, or some course of action, but it can be limiting (17). Curiosity, which wants to break loose, must be restrained so that the scope of the method or course of action is not exceeded through irrational and misleading efforts. Although it may appear irrational to do so, curiosity must, on occasion, consider that which is seemingly *beyond* reason. At the time, it wasn't "reasonable" for Kepler to consider that

[2] The five "perfect solids," each with identical faces, and in order of increasing number of faces are: tetrahedron (4), cube (6), octahedron (8), dodecahedron (12), and icosahedron (20).

planetary movements could follow any orbit other than circular, because of the limited reasoning of the time (i.e., that which limited the scope of the method). The oval shape lacked the archetypal appeal of the circle which had long been a symbol of unity and infinity in the religious domain, and of pure mathematics in the scientific domain (Koestler 329). The lowest form of reason quickly tosses out "flashes of novelty" if those ideas don't immediately fit within a known paradigm (Whitehead 20). So what may appear at first to be irrational may indeed be rational and prove worthy of study.

It is a mistake to equate traditional values with the rational, because the traditional view may simply be wrong. Coming from a tradition wherein astrology was valued, Kepler thought that he could eventually make it a precise, empirical science. While astrology is now considered a pseudoscience, in Kepler's time (and in our time for those who still believe in it) it offered the benefit of relating the individual to something much larger (viz., the cosmos). At the present time we use biological psychiatric theory and behavioral psychology to explain why people act the way they do. But at the time of Kepler, astrology, mysticism and religion provided suitable explanations. Kepler was at least honest enough with himself to admit that he knew he could not use astrology to predict with absolute certainty (Koestler 245). But his anecdotal successes (or coincidences) with astrological predictions still played a role in his belief system.

There is an element of subjectivity when discerning between the rational and the irrational. It is often a matter of relativity, and it evolves over time along with the process of discovery. It was once considered irrational to believe that the earth was spherical, so lessons of the past should show us that we must continually move beyond limiting beliefs. We should be aware of our own potential limitations, regardless of the era. For example, a current potentially limiting belief in astrophysics (that might someday be proven wrong) is that nothing can travel

faster than the speed of light.

The psychological process of discovery is not a purely linear process. At most it is *roughly* linear over time. Bronowski noted that what a scientist does is composed "of two interests: the interest of his time and his own interest" (8). What a scientist is interested in studying and what he does with his time to fulfill that study intermix during the process of discovery. One, his own interest, is not bounded by time. That interest can express itself in the mind in various manners, and there can be synchronous ideas developing at once. But when the interest is manifested in the physical world through procedure, testing, and study, it needs to follow a more linear progression forward through time. But it can never be a purely linear process since the mind is always involved during that process. The mind takes detours, considers multiple options, and sometimes holds onto premises and assumptions that are invalid, thereby slowing the process of discovery.

As Kepler progressed throughout his career, the trend was to increasingly substitute logical constructions for irrational assumptions and inferences. The older he got, the more refined his approach became with objective mathematical reliance. For example, he eventually realized that the orbits of the planets were mechanistic and non-possessing of free will. There was a balancing between his mistakes and his steadfast resolve to continue onward. Kepler's maturing toward objectivity is not only what we should expect from a scientist over a lifetime, but also from the scientific community as a collective whole, and methodology should improve and evolve over time with a cooperative attitude.

Some of Kepler's mistakes had been due to imagining order where it didn't belong. We all seek order, structure, and the familiar. We see order every day in our lives, and we value and rely on that order. We value it so much that we can often be mistaken by its appearances. Almost

anyone who has stared into the branches and leaves of a tree has seen a face or some other recognizable figure. Our mind instinctively looks for order amidst chaos, and it is a scientific error in the making to *force* order where none should exist. One mistake Kepler made was in overlooking small errors and allowing invalid assumptions that didn't quite fit perfectly with his preconceptions.

It is certainly the business of science to find order and to recognize new patterns in the world. That it may be difficult to obtain objective proof should not limit its progress. The discoveries not only of science, but also of artistic endeavors, are explorations of hidden similarities of nature, and the discoverer (or the artist) presents two or more of them together and fuses them into one new idea, concept, or theory. This is reflective of the act of creation or discovery. Unlike the artist, however, the scientist must conform to the facts and recognize that "the sanction of truth is an exact boundary which encloses him" (Bronowski 28). But the very fact of pushing toward new boundaries is the essence of discovery.

Sometimes faith and belief are incredibly strong and they force one to hold steadfast to beliefs that may be irrational. There is always a struggle between faith and doubt when trying to understand the unknown. Saint Thomas Acquinas (1225–1274) believed that faith was a higher guide to truth than knowledge because some concepts are held "by authority or the conviction that they are self evident" (Bronowski 45). Not all concepts can be easily tested, if at all, and faith binds them to a belief system. Unfortunately, this faith opens the door for the possibility of irrationality. In contrast to the belief of Saint Thomas Acquinas, there have been others, like Peter Abelard (1079–1142), who believed that there was value in the act of doubting because it forced us to examine, inquire, and experiment, thereby placing us closer to the truth.

Whitehead discussed two types of reason—that which is above and beyond worldly

affairs, and that which directly involves worldly affairs. He wrote that every experience is dipolar since the mental experience is always integrated with and inseparable from the physical experience (32). The first type of reason is associated with thinking, pondering, and cogitation, and involves the striving for an all-inclusive understanding of the world. The second type of reason is associated with accomplishing tasks and solving the problems of the day. Kepler is an example of one who used both types of reason during his research. He wanted to understand how everything fit together from an existential perspective—an all inclusiveness, yet he also used his knowledge, curiosity, and skills to try to mathematically solve the mysteries of planetary orbits in our solar system.

There is a psychological process that goes hand-in-hand with the accumulation of facts for the scientist. To participate in the process of discovery means that speculation must be encouraged. Whitehead warned against obscurantism, which is the refusal to speculate freely beyond the limitations of traditional methods (43). He also observed that a balance must be drawn between speculative reason where any and all ideas may be considered, and methodic reason where discipline and discernment must be a priority (65). The two must be fused so that speculation itself becomes more of a discipline, with the overall objective being not necessarily discovery, but rather progress, because it is progress that helps expand existing boundaries.

Bronowski observed that no scientific theory is merely a collection of facts (i.e., raw data). Facts are certainly "true," but they are sometimes only relatively true, and combining truths does not necessarily make a valid larger truth in the form of scientific theory (12). The process of discovery, according to Bronowski, has three steps: gathering raw data, finding order in that data, and creating a symbol, a concept, or a theory to explain the new order of that data (31). Kepler's problem was with the third step. He was not able to offer a central concept or

explanatory theory, and therefore wasn't able to place his discoveries within a plausible paradigm. There must be a sense of bonding between the first step of gathering data and the second step of organizing that data in a meaningful way. Similarly, there must also be a bonding between the order created in step two and a clear concept or theory in the third step to have meaning that extends beyond a particular discovery (with its associated collection of facts).

There are few occasions when the process of discovery will not be accompanied by difficulties. Family matters, sickness, deaths of loved ones, concern with ridicule, difficulty in getting funding, absence of adequate tools—all play a role and take their toll. Kepler experienced numerous hardships in his life, and each affected him and forced him to strengthen his resolve to continue. For example, upon its completion, it took four years for Kepler's New Astronomy[3] to be published due to lack of funding for printing and also to squabbles with the heirs of his former colleague, Tycho Brahe, regarding the latter's research materials.

Reluctance to be open-minded is also a hindrance to the process of discovery. Kepler, for example, rejected the idea that Galileo had discovered four new planets because he still believed that there could be no more than five perfect solids, and therefore no more than six planets could be conjoined within their geometrical shapes. Thus, Kepler said Galileo's discoveries must be moons, not planets. He was right—they were moons of Jupiter—but he was right for the wrong reasons. On more than one occasion Kepler's invalid assumptions led him down avenues of research that ultimately proved fruitful in other ways. It is therefore of value to continue onward despite errors (recognized or unrecognized) because those errors may be the fertile seeds of future discoveries. Keeping a log of errors is invaluable on the path of discovery, as it forces one to self-check, and helps others avoid the same errors.

[3] Published in 1609, the full title was A NEW ASTRONOMY Based on Causation of A PHYSICS OF THE SKY derived from Investigations of the MOTIONS OF THE STAR MARS Founded on Observations of THE NOBLE TYCHO BRAHE.

Humans are both rational and irrational, to varying degrees, and it is easier to be rational when involved in the routine events of everyday life. It is only when we go beyond the simple toward the complex that irrationality creeps in and threatens to assume a larger portion of the psychological process. But as issues at hand become more complex, it is even more difficult to recognize the presence of irrationality, and it is not easy to even ascertain pertinent questions about a problem. It is therefore important to have a rigorous system in place. Perhaps the most important thing that Kepler learned from his colleague Tycho Brahe was that astronomy needed precision in the form of continuous observational data (Koestler 285). Brahe had a keen sense of patience, a trait required for precision and the recording of continuous data. With that mass of data, it was easier to observe trends and patterns that were repetitious and measurable.

Like philosophy and theology, the purpose of science is to realize truth. But focus should not be placed only on the end discovery. The *process* of exploration should be valued no less than equally with the discovery itself, because it is only by that process that additional discoveries will be forthcoming. That process of exploration involves thinking, the welcoming of an ebb and flow of considerations, ideas and examinations—all for the purposes of improving the process, but still with the end in mind. The function of reason is to allow what is imagined to become realized. The path of discovery includes reason as its dominant checking mechanism. Rationality is the ability of humans to use reason. Through thought, and expressed through the tools of language and writing, explorations are made, abstract ideas are expressed in structured form and recorded, and are then eventually published or publicly shared.

Koestler's account of Kepler's life illustrated the changing relationship between faith and reason. For discoveries to be made, there must be a harmonious relationship between the two. Kepler's beliefs were a mix of the metaphysical on one hand, and the modern and empirically

scientific on the other hand. While he was ahead of his time in thought, it was difficult to break out of the dogma of the medieval church and embrace a purely scientific frame of mind, and he was never able to completely do so. His mindset, with an occasionally semi-deluded disposition, worked to his benefit by keeping him engaged in the process of discovery. Perhaps scientists should be less rational, because when they think creatively, they force open new doors with their ideas. They must break beyond the boundaries of existing paradigms to either expand those paradigms or create new ones. Kepler had wanted to see order so badly that he held on to erroneous ideas for too long. But by doing so, he did eventually find order, just not an order that fit with his often irrational preconceived ideas, and it was therefore difficult for Kepler to fully realize the importance of what he had discovered.

Humans have a need to explore and improve upon life, and this need is evident not only in the sciences, but also in the arts and in all fields of endeavor. The psychological process of discovery in almost any field of study is indeed complex. To complicate the issue even further, it must be recognized that each individual proceeds differently. No two paths to discovery are precisely the same, regardless of the imposed rigor and discipline involved. It is, therefore, of utmost importance that a system of common ground be utilized by all. That common ground should include the encouragement of unbounded curiosity, perseverance, self-discipline, periodic individual review, periodic peer review, honesty, and the willingness to discard conventional wisdom when necessary and start from scratch. With such a structure, the rational assumes its proper place in the psychological process of discovery.

Works Cited

Bronowski, J. Science and Human Values. 1956. New York: Harper and Row, 1965.

Koestler, Arthur. The Sleepwalkers. New York: Grosset & Dunlap, 1963.

Whitehead, Alfred North. The Function of Reason. Boston: Beacon, 1929.