Engineering & Applied Mathematics Imagination Retreat

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Philadelphia, Pennsylvania

Report by Kristy Johnson

Mathematics and engineering are disciplines that, almost by definition, seek an absolute answer, a right or a wrong, a success or a failure. The proof is correct, or it's not; the particle exists, or it does not; the ship can withstand the impact of a wayward iceberg, or it cannot. How, then, does imagination – a topic that evokes depictions of fanciful unicorns and meatballs raining from the sky – fit into these fields? Is it possible to be an imaginative mathematician or engineer, and if so, how would such a person think? Moreover, how does one cultivate imagination in math and engineering, or assess whether an idea or person is "imaginative"?

To probe these questions and many more, the Imagination Institute invited a gathering of scientists, engineers, and applied mathematicians to Philadelphia in early February 2017. Attendees included:

- **Danielle (Dani) Bassett** – Associate Professor of Bioengineering, University of Pennsylvania
- **Robert Ghrist** – Professor of Applied Mathematics and Electrical & Systems, University of Pennsylvania
- **James (Jim) Hovey** – Vice Chairman, Eisenhower Fellowships
- **Elizabeth (Lizzy) Hyde** – Research Coordinator, Imagination Institute
- **Kristina (Kristy) Johnson** – Doctoral Student and Learning Innovation Fellow, Affective Computing Group, MIT
- **Scott Barry Kaufman** – Scientific Director, Imagination Institute
- **Kimon Sargeant** – Vice President of Programs, John Templeton Foundation (Friday dinner only)
- **Martin (Marty) Seligman** – Executive Director, Imagination Institute
- **Seeta Sistla** – Assistant Professor of Ecosystem Ecology, Hampshire College
- **Steven (Steve) Strogatz** – Professor of Applied Mathematics, Cornell University
- **Perry Zurn** – Assistant Professor of Philosophy, American University; Center for Curiosity Fellow, University of Pennsylvania

This small but determined group of analytical thinkers probed the topics of imagination, curiosity, and creativity over the course of three days. As outlined by the Templeton Foundation, the retreat had two goals:

> 1) Find and develop imaginative minds in mathematics and engineering.
> 2) Expand the amount of imagination in the world by making every person more imaginative.

The conversation was largely unprompted, eliciting non sequitur discussions covering the induction of awe, how multi-dimensional ideas are converted to linear outputs, and what the brain does when it's not supposed to be doing anything. Participants explored the role of failure in innovation, obsessive versus harmonious passion, and what makes concepts "sticky." They debated the politics of curiosity, the compassion of imagination, and the calculus of friendship. They even swapped stories about Carl Sagan and bridge. It was a lively and memorable few days.

What does imagination in applied mathematics and engineering look like?

Contrary to every previous event, this Imagination Retreat opened with presentations from participants on projects related to the imagination or the creative process. First met with marked skepticism, perhaps even criticism, for their formality, the presentations were later acknowledged to be beneficial (perhaps even superior to a program without them) because they rapidly directed the conversation toward deeper questions and ideas. Indeed, according to Institute members, this group of participants jumped into the "deep end" of questions and topics faster than any other group to date, and the intensity continued throughout the weekend.

Imagination as a network

To kick off the presentations, network neuroscientist Dani Bassett introduced her work using network theory to understand the dynamics of human thought. For example, how does the flexibility of thought – represented by malleable brain networks – relate to optimal cognitive function? Current theory suggests that flexibility and cognitive function have an "inverse-U" relationship, with childlike playfulness being highly flexible but lacking optimal utility while mental disorders like schizophrenia facilitate faster-than-usual transitions between thoughts but reduce overall cognitive function. Somewhere in the middle lies a range of flexibility that enables expansive cognitive capabilities, facilitating new connections and innovative ideas.

Building on this foundation, Bassett was working to discover and mathematically describe the network architecture of curious thought. How does each person build his or her own knowledge network? This architectural process likely differs for each person, incorporating his or her personality, background, and environment, but there may be similarities that generalize, categorizing people who love disparate information like trivia from those who prefer to interweave every piece of information they encounter.

Bassett's group was also exploring the linearization of multi-dimensional thought. Suppose that imagination – or perhaps any idea – is multi-dimensional in origin, traversing time and space. How, then, does a person translate that idea into writing or speech which is, necessarily, uni-dimensional in time? As with knowledge networks, each person's linearization process likely results in a different outcome, but by understanding these processes, one can begin to understand how to teach and learn for maximal impact.

Imagination as a math class

Robert Ghrist presented another perspective, asking how we can teach imagination through mathematics. For him, the answer meant using the medium of video to teach calculus rather than more traditional approaches. He presented his widely popular Coursera MOOC (Massive Online Open Course) on single-variable calculus, emphasizing that the new platform allowed him to reach an audience that might otherwise not have approached calculus – or stuck with it.

"Why are you so excited about math?" Institute scientific director Scott Barry Kaufman asked Ghrist after his presentation.

That wasn't the right question, Ghrist explained. "The right question to ask me is what type of video game do I like, and the type of video game I like is the type where it's an open world and you start off and you can go anywhere and if you go to the right spot and you look in the right place, you find something amazing. … This whole idea of the undiscovered country and the lone traveler who can go where no one else has been before, that is romantic. It's gripping. That is what I love about mathematics."

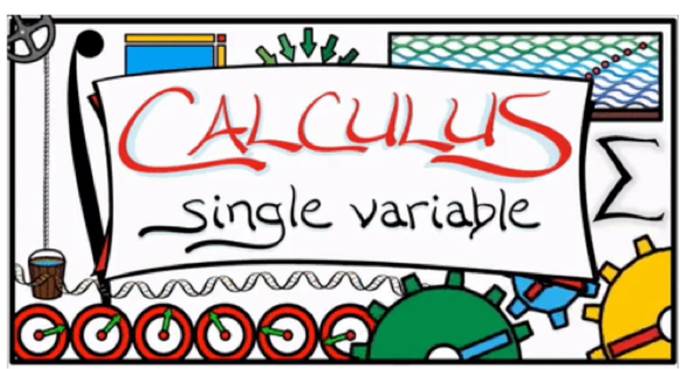
Imagination as philosophy

Next up was Perry Zurn, a philosopher whose corpus centered on curiosity. He defined curiosity, in part, as an exploration, a desire to know – or perhaps a "desire to seem to know," from a post-capitalist, lust-for-social-standing perspective – and thinking the "inostensible." Curiosity, he explained, used to be considered a disease.

He outlined several "modes" of curiosity, from the socially-fueled curiosity of the "busybody" who asks, "What's new?" to the dogged solitary pursuit of the "hunter" who asks, "What is?" to the leaps of the "dancer" who asks, "What if?" Ghrist's video game mathematician model, he explained, was "a figure of curiosity. The open landscape of discovery and the single explorer."

Then Zurn began to disentangle the relationship between curiosity and imagination. Although personality assessments, like the lexicon-based Big Five model, correlate both of these processes with individuals who are "open to new ideas," he argued that curiosity and imagination were fundamentally distinct. Moreover, the migration from one process to the other was significant. For example, an individual traveling from curiosity to imagination might try everything until he can't find a solution (curiosity); then he must try something that does not exist (imagination). Conversely, the path from imagination to curiosity might involve thinking of something that does not yet exist (imagination) and then trying them all out.

Anecdotally, it seems that most scientists and mathematicians pursue the former process, marching through solutions until they must invent their own. However, one could perhaps argue that the famous mathematician Ramanujan, who grew up in a small Indian village with little to no formal training and yet produced hundreds of pages of novel variations on



Robert Ghrist's *Calculus: Single Variable* massive open online course (MOOC) teaches the fundamentals of advanced mathematics through engaging and interactive graphics.

mathematics, employed the second route, first imagining mathematics in a new form and then examining each notion.

Which process is better? One can only imagine...

Imagination as scales

As a systems ecologist, Seeta Sistla described the necessity of intimately understanding the vast expanse of scales in nature. For example, the relevant time scale for a microorganism in permafrost soil is very different than the time scale for a human, which is very different from the scale relevant for a shrub. One must connect that which often cannot be seen or felt or heard, which critically requires imagination. “Big numbers are confusing to people,” Sistla explained. “Very small units of measurement or very big measurements are confusing because they're outside of the range that we normally experience.” To understand how ecosystems respond to change, one must be able to traverse these scales fluidly. Both researchers and citizens must imagine what they *might* do, or how they *might* feel in order to empathize, anticipate, and thrive.

Mathematician Steve Strogatz provided an apt analogy: “How long do you think a million seconds is, related to your life? How long is a billion seconds? What does it feel like?”

“A billion seconds feels like immortality,” responded Marty Seligman. “Or damn close to it.”

“It feels like a lifetime to me,” answered Scott Barry Kaufman.

A million seconds, it turns out, is about 11 days. Two weeks from now, a million seconds will have gone by. A billion seconds is 32 years – a good fraction of one’s lifetime. Clearly, Strogatz pointed out, we should not lump millionaires and billionaires together as if they were the same, as politicians are wont to do. And a trillion seconds? That’s 32,000 years. “[That’s] very hard to think about… and yet, our national budget is in the trillions.”

Part of being a scientist, an engineer, or a mathematician is being able to imagine how the world (even the universe!) functions at nearly unimaginable scales.

How do you solve problems? How do you find the right problem to solve?

When participants were asked to describe their thought process when solving a problem, there was some controversy over the difference and significance of solving problems versus choosing the right problem to solve. For some, these processes were the same; yet for others, finding the problem was the heart of the matter. Nevertheless, they all had a process.

Ghrist described going into “the zone,” requiring over an hour of concentrated work to achieve this state, similar to lucid dreaming. He could then visualize his ideas and manipulate them with relative ease.

Bassett let her mind wander during boring lectures, describing the process as a “biased walk through idea space.” The background hum of the lecture allowed her to muse about a thorny problem, sketching ideas – just pictures, rarely words or math – for further exploration. Some tangential comment or “germ of an analogy” from the lecture would often render a new connection to solve a difficult problem.

But it needed to be a *bad* lecture – not just any afternoon colloquium would do. “I need the boredom,” Bassett explained. “I need to feel the need to escape.” Her mind was the outlet, allowing her to stay physically present to meet social demands, but providing the freedom to escape through her ideas.

Kristy Johnson described her days as an avid cyclist, spending hours on a bicycle: the background stimuli was low enough to allow her to focus on a tricky problem, yet high enough to keep her senses sharp. For her, thinking required movement.

Strogatz answered that he sought simplicity, chipping away at a problem – often a problem that other people assumed had been solved completely – to get to its roots. “I love simplicity, and I've made a career out of asking really simple things that people tell me, ‘Why are you doing that? That's already understood.’” They are often wrong, he explained. “I think the easier stuff is often not that easy. The fundamentals are endlessly rich and interesting.”

Sistla took a similarly contrarian approach, wondering why a place looks or functions the way it does and questioning how it could be different. “How much of a perturbation do you need to shift it from one state to another?” she would often muse. Not only that, but why do some systems change in one way, and others respond so differently? “I’m interested in the resilience versus resistance of systems.” This process leads to seemingly infinite avenues for exploration.

For Zurn, unstated assumptions were a heuristic for fruitful study. Anything “accepted without question, taken for granted, passed over, and yet used excessively” – that, to him, was the hallmark of a good problem or topic. “I want to make it hard for you to say that word again without thinking, without feeling the weight of its complexity.”

What’s the difference between crazy and creative?

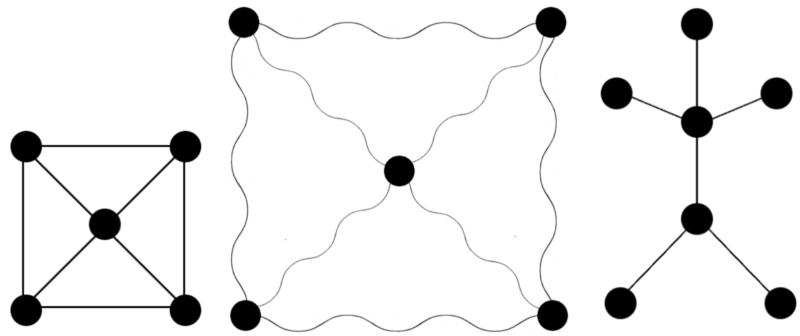
Working towards an understanding of the cognitive processes associated with imagination, Kaufman first defined imagination as “the ability to represent things that aren’t immediately present to your senses.” So then, what is mathematical or engineering imagination? Is it just something original?

Bassett felt originality and imagination might be distinct features. For example, the graduate student who suggests an idea that is very original but that also disobeys certain laws, rendering it most likely incorrect – “Is that imaginative or just crazy?” she asked. Likewise, something might be original to a researcher or her field, but if it’s obvious to everyone else, then perhaps it is only imaginative within a narrow domain, lacking profound generalization.

The fine line between crazy and creative sparked a discussion on the *functionality* of ideas in applied mathematics and engineering. Perhaps one could start with a big crazy idea and boil it down into something more manageable. “Concept cars at auto shows,” Jim Hovey suggested as an example. “Nobody expects to see them on the road,” but they are working toward immense technological advances. Johnson agreed: “It starts with the dream vision of what I want and comes down to the thing that I can do right now, today.”

But Strogatz felt that staying in the domain of “crazy” was just fine, if that worked for you. One of his early problems on small-world networks was considered grandiose – and for some, ridiculous – when he first began. “When my student said, ‘If we could make progress on this, it would affect everything,’ … we knew there was something interesting in it.” Their resulting paper has now been cited over 33,000 times.

Is too much creativity bad for your career?



Mechanical representations of connectivity between disciplines or ideas, suggesting that closer connections – e.g., ideas within a single discipline – might have a more rigid structure like the diagram on the left. Ideas that connect more disparate fields would result in more pliable, or "squishy," connections, like the middle diagram. An alternative solution, providing both breadth and structural support, might be an appendage model with divergent ideas connected to a central core.

Following the "crazy versus creative" conversation, it came to light that doing the most creative work was not always the recommended path to career success. "In my first year," Bassett said, "[I was told] to pursue relatively straightforward ideas at a consistent pace for five years and hope to get one brilliant idea, but not to make that the focus." To achieve tenure, she said, "You're still supposed to find the big idea, but not without some steady work."

Zurn added that not only does the work need to be paced, "but it also has to be centered in some kind of recognizable stream." Strogatz agreed: "You have to get people who can write for you." In fact, early in his career, he was told that mathematical biology was too "squishy" and initially struggled to find a home between mathematics and biology. "The great universities don't have mathematical biologists, certainly not in math departments."

Always the network scientist, Bassett suggested that "squishy" could be thought of in terms of the mechanical rigidity of a network. Problems and ideas that fit neatly into our existing bodies of knowledge are tight; they are mechanically rigid. However, if an idea is far away from the established bodies, then "it's going to be quite squishy."

Of course, that does not mean bad. "Squishy is good. Squishy pushes boundaries," Johnson pointed out. "All hail squishiness!" Strogatz concluded to a room of chuckles.

In order to find the right structure that might be most conducive to inventive interdisciplinary work, but that also did not hamper one's career, Bassett suggested to "think about it in terms of bodies with appendages… structurally connected to the core." If one can draw connections to the central knowledge base, then it might just give an innovative idea the foundational support it needs to thrive.

This technique still does not overcome the apparent systemic hierarchy in the sciences, whereby certain sciences were referred to as "hard," as if they had "more real science," Sistla pointed out. "It devalues certain ways of thinking or approaching problems and overvalues others. It hinders creativity and collaboration, too." Only by recognizing the contribution of the various different fields and subfields could one truly break new ground.

Zurn noted that there is also a social stereotype or class problem regarding *who* is capable of producing creative work. "There's a lot of data demonstrating that people, based on their name or their appearance or their ethnicity, are perceived already as less rigorous, less prepared, less apt to come up with an original idea." As a consequence, their ideas and perspectives are not heard, potentially reducing the creativity in the field.

Some discussion emerged over whether society should provide more resources to overcome these biases or whether people should adapt, suggesting that evolution would self-select the most exceptional individuals. However, several participants countered that the problem was more complicated than survival of the fittest. "It's not the individual organism that adapts," Strogatz noted. "It's the population." Often, people survive because they have the background, network, and support – not necessarily because they are the best.

"My instinct [tells me]," noted Sistla, "that by having this extreme competition, you're winnowing out the most creative people."

When it comes to collaborators, does creativity trump personality?

When asked how participants chose their collaborators, Ghrist started the conversation by stating that he prefers to work alone. However, Hovey countered that the scope and type of problem were integral considerations. You can't, for example, put a man on the moon by yourself, he noted. Strogatz added that it wasn't just the type of problem, but also the type of the problem solving that needed to occur that mattered. Brainstorming problems, he proposed, benefited from a more social structure or environment, while technical problems were best tackled by oneself.

Surprisingly, the group generally conceded that most collaborators were not chosen for their skillset; rather, they were selected based on their personalities and qualities of endearment or friendship. In fact, the concept of friendship or "liking" the other person outranked traits of creativity or other abilities. In other words, "Chemistry matters," Kaufman concluded.

Perhaps this idea speaks to the need to develop "soft" personable skills over more technical or even "creative" skills?

Does being a mathematician or engineer change your personality?

Early in the weekend, the topic came up as to whether being a mathematician or engineer could make someone more autistic. That is, when they first enter the field or begin their work, they may present with traits more along the "neurotypical" spectrum, but after many years in the field, they appear to have more traits along the autism spectrum, such as divergent responses to social situations.

Ghrist pointed out that not only was this a phenomenon he had witnessed, but it was not purely a selection process. He referenced studies that assessed people before intensive training in graduate level mathematics and then after, and showed that they moved along the spectrum.

Seligman noted that there was even modern literature showing a reciprocal relationship between the social areas of the brain and the mathematical ones, suggesting that as one area of the brain strengthens, the other one suffers. This phenomenon was similar to the ways in which a London taxi driver's brain changed as s/he learned all the streets in London.

Johnson suggested that the act of immersing oneself in the types of thinking required for mathematics or science pruned certain areas of the brain while strengthening others. In her view, it was possible to have a predisposition for certain traits like alcoholism, depression, or even creativity or introversion, but it was through the process of practice that these traits became core features of one’s personality.

$$e^x, \widetilde{\omega}, \tau$$

Notation as characters: the exponential function, omega twiddle, and tao.

Similarly, mathematics and engineering are disciplines that encourage a person to get lost in a specific, hyper-focused logical line of thinking, which can be a hallmark of autism. Individuals on the autism spectrum value routine and the predictable structure of methods and rules. When practicing something repeatedly, as in graduate school, it makes sense that individuals would neurally reinforce certain connections while losing other ones – e.g., skills involving social dynamics. These skills may have been developed early in their careers prior to realizing such skills were not as critical to success in mathematical, engineering, or scientific endeavors (though, arguably, they may be becoming more so).

The same neural processes could, in theory, be invoked for imagination, creativity, and curiosity-driven thought. While some individuals might have a predisposition toward imaginative thoughts or endeavors, it is the sum total of their life experiences – including their environment, genetics, peer groups, parental support, socio-economic status, and exposure to ideas – that sculpts their ultimate mental dexterity. “A born capacity does not equal a final achievement,” Zurn deftly summarized.

Could studying math, then, make an indvidual more introverted? While math does not have to be solitary, it was suggested that perhaps deep, solitary pursuits allowed individuals to delve into an idea with unfiltered concentration and creativity. In fact, Ghrist confided that he was once “really extroverted,” as measured by certain personality tests, and now, after years of mathematics immersion, he scores strongly as an introvert. “I don't dislike working with other people necessarily, as long as it's punctuated with long periods of isolation.”

The brain, Kaufman noted, appears to distinguish between visual/spatial or engineering-oriented imagination and social imagination. “We seem to be designed by natural selection to have a tension between these two modes of thought. If you have one mode of thought, it actively inhibits the other brain network for social [reasoning].”

“All the more reason to [engage in] deep solitary work then, right?” Johnson responded. Redirecting all of one’s brainpower to solve a hard problem may be the imaginative solution in today’s distracted world.

What if math were a sitcom?

If mentoring is one way to engender imagination or creativity in individuals, what are others?

For Ghrist, the answer was in the math characters. In his classes, he was often answering questions like, “Why should I care about this? Why is this exciting? How does [this concept] fit into the grand scheme of the course?” He felt he needed to find a way for the students to resonate with the material.

Now they ask, “What happens to the characters in our story this week?”

For Ghrist and his students, math characters become actual characters: “When I teach single variable calculus, the first day of class, I introduce the main character, which is e^x. A wonderful function, does a lot of good, has a real Bildungsroman story going through the entire course. It keeps coming back, playing the role.” All of a sudden, the math becomes personal, even social. Students connect with the characters, trekking alongside their adventures throughout the course.

The room buzzed with excitement. Participants had often experienced relationships with their work that transcended typical notation or even relatable descriptions. They began discussing the personality of e^x. “Myers-Briggs. Extremely extroverted,” said Kaufman, drawing laughs from the room.

Johnson then revealed that she had drafted children’s stories about the variable omega twiddle during undergraduate physics courses. Omega, a curly-haired little girl, and her best friend, Tao, traveled through the Land of Phi-Phi-Pho-Phum (“Fee-Fi-Fo-Fum”), full of mathematical adventures. “The embodiment of love, science, and childhood is Omega Twiddle,” she confided.

“We are coming out of the dark ages when it comes to courses, lectures,” Ghrist responded. “People are saying, ‘Oh, the lecture is dead. That's an outdated, outmoded, delivery mechanism,’ but I think completely the opposite. I think that the idea of a course as art is just about ready to take off.”

Referring to his Calculus Massive Open Online Course (MOOC), Ghrist continued, “The process that I went through to turn a course into something that was going to be a video on the web seen by lots and lots of people over a long period of time, made me think, ‘How can I really design this to be a coherent work of art? How can I put characters in there? How can I sneak in little symbols that show up?’ Easter eggs, if you like. ‘How could I build an architecture?’”

“I aspire to do for course building what Joyce did for the novel. I think that we've not yet explored what is possible, if you really put work into building a course, a system of lectures, as a work of art.”

When Johnson questioned whether a narrative approach to mathematics could scale – e.g., to teach differential geometry or algebraic topology or general relativity – Ghrist assured her it could. It was not a question of scaling the material, but rather, a question of devotion and dissemination. Current strategy involves building a class for one semester, for 30 students. That’s no way to build a cathedral, Ghrist pointed out. But with the advent of YouTube channels, MOOCs, and other technological advances, it’s easier to build a course that is “architecturally intricate and beautiful,” giving it permanence and impact that was previously out of reach. “It’s motivation to build something that is worthy of being watched year after year, after year, after year.”

Bassett felt the context of a course could even strengthen this approach: “You can get people addicted to the personalities the same way they are to their favorite TV show. They can't get all of it at once.” Each week, the students would be exposed to their bit of the story, but then they would have to wait, fueling their intrigue and connection to the characters.

Seligman pointed out that one of the ways he and Kaufman characterize the brain’s default network is as the ‘personal involvement’ network. “You're taking the material, but you're merging it with your personal concerns.” To which Johnson replied that Ramanujan, the Indian mathematical prodigy, was said to have been “personal friends with every positive integer.”

Watch out, world. Math is coming to prime time.

What are the “sacred cows” in mathematics and engineering?

Despite participants feeling like the question was a bit of a setup – suggesting that one idea in a field was universally more sacred than the rest – they took the bait.

What are the sacred cows in these disciplines? What values do they hold above others? Or perhaps, what is it that mathematicians and engineers are pursuing; what is the common motivator?

Past participants had named things like truth or honesty or compassion. For the improv artists, it was apparently authenticity, but for this group – it was beauty. Without skipping a beat, several participants independently acknowledged Euler’s Identity as exquisitely beautiful.

And for a man who talks about building cathedrals with calculus classes, Ghrist acknowledged that he had revered the beauty in mathematics from a young age. He described a chance encounter with an “ancient, crusty” math book that produced an almost beatific vision, inspiring him to study mathematics in order to understand what he had seen.

Yet, some people acknowledged that not having such a vision or an emotional attachment to numbers or the beauty in mathematics could be distancing. It could have the inadvertent effect of making a person feel left out, like they’re not part of The Club. Moreover, for many, the sense of beauty in mathematics did not occur until they began studying it as an adult, or they simply valued the concrete answers mathematics could provide.

What about engineering? Did it have a sacred cow?

“Efficiency,” Ghrist suggested. But that was met with skepticism. “Not as a sacred cow,” he clarified. It was valued, the room agreed, as was cleverness. Making a system work well – perhaps even coming up with a clever solution to do so – these were all core values in engineering. But in general, no one value emerged as superior to all others.

And philosophy? While Zurn, like most philosophers, valued the classic sacred cow – truth – he was also keen to explore another school of philosophy: “What is useful?” he asked. “What can we do with this concept? How can we bend it? How can we make something new?” He noted that a concept did not need to be unequivocally true to the way it was first developed or to the person who first developed it, but rather, it could evolve. He cared more about doing things with ideas than just getting them “right.”

If you had 2 million dollars to make the world more creative, what would you do?

$$e^{i\pi}+1=0$$

Euler’s Identity, widely regarded as one of the most beautiful equations in mathematics.

To close out the weekend, Seligman conveyed what he felt Jack Templeton would have asked: “If we gave you a couple million dollars to make either the top people in your field more creative or the next generation of human beings more creative, what would you do?”

With five minutes left on the clock, the room sprang to life, generally agreeing that the second endeavor – to make the world more creative, rather than just a select few – was of primary importance. And being a group of academics operating in university settings, the first suggestion was to design a course. In particular, a freshman class that could elicit mechanisms of creativity early and then strengthen them over students' college lifespan.

But what would such a course look like? Would the teacher be presenting problems that have a "right" answer? Should the professor present the problems at all? What about a course where the students select problems that are meaningful to them? Students could select a project that was personally significant to them, motivating them to think and solve creatively. They would then be invested in figuring out how to overcome the obstacles and produce a functional or valuable solution.

However, choosing a project or topic that has the proper scope, including the depth, breadth, and expertise necessary for the student to experience "success" in a reasonable timeline requires careful thought. Circling back to the early discussion on problem finding versus problem solving, Seligman suggested a course on asking the "right" questions. Imagine – a whole course dedicated to problem finding! It could be an immersive experience designed to help students discover what meaningful problems require inventive solutions and how to approach them.

But perhaps such a course would put too much pressure on "being" creative. Bassett pointed out that much of her most creative work in undergrad was done in classes where the topics were tangential to her primary pursuits. These peripheral endeavors allowed her to feel 'freer' and more imaginative because they were intrinsically motivated and lacked the constraints or pressure of work required for her major.

What about a hackathon?, several attendees suggested. Generally a weekend gathering where students converge to solve a problem, hackathons can be powerful, almost magical experiences where people experience first-hand what they are capable of creating and accomplishing in 48 hours. Yet, they often lack infrastructure for future development. Once the first prototype has been created and the weekend ends, the project often ends as well, meaning individuals never work through thorny parts of real-world problems.

But a hackathon that could become a class, using the magical fuel of the weekend to propel new ideas and then flesh them out over the course of a semester or more, could nurture powerful seeds of an imaginative generation.

As Hovey pointed out, such a course would be the equivalent of turning a one-night stand into a lasting relationship, and it would undoubtedly be full of complications. Yet, the University of Pennsylvania is already headed in that direction with its semester-long "Digital Garage" hack-based course for first-year students. And if this retreat was any indication, similar systems are sure to follow.

In fact, hacking the world to be more imaginative might be exactly what Jack Templeton would have wanted this group of mathematicians and engineers to do.