International Journal of Engineering Education Vol. 36, No. 2, pp. 732–748, 2020
Printed in Great Britain

0949-149X/91 $3.00+0.00

Regenerative Learning: A Process Based Design Approach*

ADE MABOGUNJE, NEERAJ SONALKAR and LARRY LEIFER
Center for Design Research, 424 Panama Mall, Stanford University, Stanford, CA94305, USA. E-mail: ade@stanford.edu, sonalkar@stanford.edu, leifer@stanford.edu

NEELIMA PARASKER
SnapIT Solutions, 12022 Blue Valley Parkway, Overland Park, KS 66213, USA. E-mail: neelima@snapit.solutions

MARK BEAM
Kauffman Foundation, 4801 Rockhill Rd, Kansas City, MO 64110, USA. E-mail: mark@beaming.com

The paper addresses the question – How do we design a process that will enable people who do not have access to design education to learn embodied knowledge at a time when there is a major shift in the dominant technology in society? In normal times, the conventional approach is to enroll in a four-year degree college or a community college, and thereafter go to work in industry. However, this conventional approach is time-consuming for the students, and impractical for companies, who, faced with the disruption of innovation often require employees with several years of experience. Thus, a gap between knowing and doing is created which does not serve well those who need to learn and earn at the same time. We therefore propose a regenerative learning paradigm for design education. We support this proposal with a case study of SnapIT, a design development firm in the software industry, and present a theory which helps us understand the regenerative learning paradigm and process.

Keywords: design education; software development; innovation; disruption; learning; regeneration

1. Introduction

Today, engineering design educators are being asked to scale up their delivery by university administrators. The dominant model that is being followed is that of process efficiency – add more students to existing courses, add more courses to increase the number of students. By process we mean both of two things[1]. First, the sequence of activities to produce an effect, and that sequence can then be automated to produce the effect, sometimes at a larger scale. Second, the combination of resources to produce an artifact and that combination can then be automated to produce the artifact, sometimes at a larger scale. Design learning is an example of the former and product design is an example of the latter. Thus, we find that technologies like Massive Open Online Courses (MOOCs) are being explored for their efficacy in optimizing the utilization of design education resources. The optimization process model tends to prioritize knowing over doing and has the potential to severely limit the development of embodied design knowledge in students and compromise their design self-efficacy.

Concurrently, innovation is an important topic for most organizations. Many business organizations are coming to believe that innovation is critical to their market position in a fast-changing world. Customers expect the companies they buy from to be knowledgeable about their changing environments and to help them address the emerging challenges and aspirations that they are discovering. However, innovation is often disruptive to process optimization. This could mean that the processes being taught in the Universities are no longer applicable in the Industry, the graduation rates of students with the requisite skills is insufficient to meet industry demands, the types of students being admitted into Universities are no longer the types of graduates Industry needs, or the types of jobs Industry has to offer are not the types of jobs graduate students want. Thus, there appears to be a phase after the introduction of an innovation in which it seems process ceases to exist. The old processes are no longer relevant, and the new processes have yet to emerge. This is a phase that is of interest to us. It is a phase that is not solely about the design process as in product design or engineering design, nor is it solely about the learning process as in undergraduate education or professional development.

One of our co-authors is a business leader and after learning about her work, we believe her response to a crisis situation in her community paralleled the regeneration cycle in thermodynamics. In this paper we would like to explore the similarity between the regeneration cycle in thermodynamics and the regeneration cycle in business

[1] For an extended discussion of this dual perspective on process, please see Donald Schon's paper on the topic [1].

* Accepted 12 November 2019.

with a view towards developing an alternative to the optimization process model of learning. We call this process regenerative learning. In order to see and appreciate the need for regenerative learning, we must make a detour from the linear progression of our writing in order to describe the context of the disruption we now find ourselves. Some readers who are used to a more linear style of writing may consider this detour as tangential and other readers used to a contextual way of writing will be less critical. However, even the context is also disrupted, for this is the nature of innovation. The reader is also warned in advance that there will be a similar jump towards the end of the paper when discussing our observations. Thus, regeneration is a process we see as necessary to restoring a new level of process and context equilibrium after a period of disruption.

2. A New Era and a New Paradigm[2]

While the industrial age powered by mechanization has given us the ability to create and distribute almost any product or service at scale to large sectors of the human population, it is worthwhile to note that this development has come at the expense of damage to the Earth's climate and at the expense of many who have been marginalized and left without secure access to basic needs. The industrial era arose from a Newtonian understanding of reality where everything can be broken into smaller component parts. Specialization, assembly lines, hierarchical organizational charts, and the time clock all allowed us to systemize production, to break down our goals and translate them into component tasks and processes. At the same time, we shifted the purpose of education from helping people lift themselves up to training people to work in the industrial production system.

Today our leading-edge scientific understanding of nature leads us in a vastly different direction. Quantum physics and Relativity Theory describe unified fields of energy and waves of probability affected by the act of observing the environment itself. Where we choose to place our attention affects the outcome. Just as importantly the metaphor or lens through which we see the world is the world we see and affect. If we see the world as a machine, we become machine like, if we look through the lens of finance, we become human resources, if we focus on technology, we see ourselves as autonomous robots. In other words, the lens with which we view the world determines our experience of it.

Quantum theory posits that everything is connected, compelling a much more holistic view of reality. Fluid socio-cultural environments that overlap and intertwine, sometimes visible, sometimes not. Waves of change that rise and fall like a sea of organisms that self-organize themselves in response to the environment. This would be analogous to individuals in open meaningful dialogue across silos allowing each to see a larger, more complex picture of their own environment. It is our contention that in order for our contemporary socio-economic systems to serve humanity in the current era, they must mirror our contemporary scientific paradigm, in the same way our industrial age systems mirrored the dominant scientific paradigm of its time. In doing so we have the possibility to find paths of least resistance and an underlying integrity to underpin a new operating system at nested scales – as individuals, as teams, as communities, as regions, and as a planet.

[2] This section is from Mark Beam's unpublished manuscript [2].

2.1 Impact of Technological Acceleration on Society

The World Economic Forum now refers to the current time period as the Fourth Industrial Revolution. The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country, and the breadth and depth of these changes herald the transformation of entire systems of production, management, and governance [3]. The result is that most people are unprepared for the profound cultural changes that are accompanying the adoption of these new forms of media and they feel increasingly confused and disoriented. While the rise of the Internet and social media have enabled unprecedented knowledge sharing capabilities, at the same time they leave us feeling overwhelmed and overloaded. A barrage of messages and data come at us asking for our immediate attention and distract us from more rigorous long term thinking and a healthy work/life balance. This state of "Present Shock" of living an "always on everything now" culture [4] stresses us out leading to a very personal toll that includes higher rates of anxiety, depression and suicide. This points to an urgent need to study and plan for the unintended consequences of moving at higher speeds.

Those least prepared for this acceleration are large segments of the population that have been marginalized and are without access to these new technologies and resources to fund media literacy programs that could allow them to compete for the opportunities afforded by new media. Just 39% of Americans say they have enough savings to cover a $1,000 emergency room visit or car repair, according to BankRate [5]. Thus, for people in these marginalized communities, Present Shock manifests as an even greater challenge in their quest for day to day survival. In other words, at the level of the individual, both the haves and the have nots are unable to step back, slow down and address the underlying cause of their distress, much less allow them to think long-term and to consciously design an aspirational future for themselves. At a systems level the news is not much better. Developed for an age whose time has passed, our major institutions have codified a fragmented approach toward meeting society's needs. Embedded within them are hierarchical, command/control structures which have become calcified and reinforce the status quo. This has the effect of reinforcing a set of cultural practices that were defined decades ago in response to a very different set of circumstances. It is no surprise then that we lack the moral will and culture to address climate change induced species extinction and the widening gap between those with access to resources and those without. Our mainstream operating system simply lacks built-in mechanisms for adaptation.

The task of changing the existing system seems daunting. The hitherto ideal mindset to change our circumstances is in decline, that is individual-based entrepreneurial endeavor. In its place, a new mindset is coming into play – that is team-based, community oriented, entrepreneurial endeavor, however this is much slower. Thus, true innovation is in danger of becoming extinct if we do not preserve a culture that can sustain it, beginning with a new culture of learning.

2.2 Impact of Technological Acceleration on Youth Culture

The leveling of the playing field in access to knowledge frees humans from having to be specialists. In fact, it discourages it because what is necessary to know changes so frequently. Today's youth need to learn as quickly as the environment shifts. Rather than forcing fragmented, specialist skills for jobs, we must move to understanding the dynamics of whole environments where people can participate as role players, allowing them to adapt as their interests, and the environment, shifts in unison. The increased complexity resulting from increased connectivity will require our youth to understand how different fields connect to each other to create our environments. This will require diverse perspectives into these environments and interdisciplinary collaboration.

Inundated with extreme amounts of data since birth, kids today can learn virtually anything online. This is both hugely enabling but also can be quite distracting and confusing without media literacy skills. Young people are discovering who they are and where their interests lie online. In the virtual world there are no limits to what they can learn or what they might do or become. Gaming actually prepares them to be role players in new worlds where they compete and collaborate with players around the world. Each game world requires them to adapt to changing environments with varying sets of powers, tools or skills. The new mindset embedded in the game world actually allows them to see how everything connects to the whole – to see how different disciplines offer alternative perspectives that together offer better, more comprehensive understanding of the world providing a basis for action. They zoom out to see the entire world and then zoom back in to one field of action or another executing strategies informed by the whole environment.

Yet in physical reality, our youth are expected to fit into a single world with a singular focus, and our schools continue this culture of specialized learning by narrowing their skills to meet undefined and largely unpredictable jobs of the future. Rather than offering new approaches for addressing the radically different world they have inherited; our youth are stuck in the outdated Newtonian paradigm. This is culturally reinforced by individualism. Everyone for themselves. This is inapposite to what will be required of them as rapid shifts will require them to learn how to learn quickly in diverse teams.

We hope this detour describing the world of our students, and the context of the disruption in which we now find ourselves helps the reader appreciate why the process of education can no longer be one of "processes as usual." We will now describe the regeneration cycle in thermodynamics and the regeneration cycle in business, and then present the model of SnapIT our co-author's company as a prototype of what regenerative learning might look like.

3. Regeneration

Thermodynamic Theory: One of the principles used to improve the efficiency of the process cycle on which steam power plants operate is to increase the fluid average temperature during heat addition and decrease the fluid temperature during heat rejection. In a simple Rankine cycle (Fig. 1a), heat is added to the feedwater (water leaving the pump) during process 2–2′–3. However, the lower temperature of the water in the segment 2–2′ reduces the average temperature for the entire process 2–2′–3. To remedy this shortcoming steam can be extracted from the turbine to heat the feedwater thus increasing the temperature of the feedwater (see Fig. 1b). This process is called regeneration and the heat exchanger where heat is transferred from steam to feedwater is called a regenerator [6].

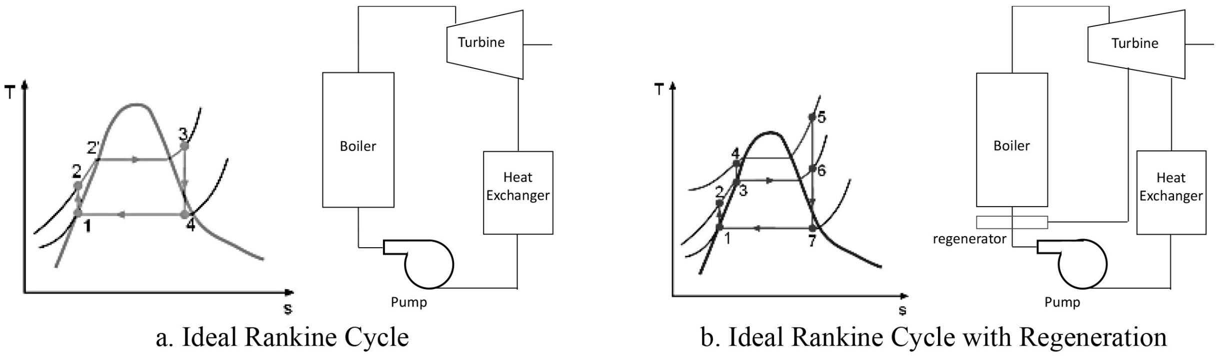

Fig. 1. The Ideal Rankine Cycle and the Ideal Rankine Cycle with Regeneration.

In the typical education cycle, students learn and then go to work. What if we invite students to join a work environment in the community where skilled professionals mix with and teach them? This process is what we are calling regenerative learning. Before going on to describe the specifics of the model as implemented in SnapIT the company whose model is being compared to the regeneration cycle, it will be useful to briefly explore how the term is being used to describe similar processes in other fields, in particular Medicine and Plant Biology, and how it is being adapted for use in Business. We believe this will enrich our discussion, as well as give people not accustomed to its use in thermodynamics a different metaphor that they can use to understand the subtleties of our description and discussion.

3.1 Plant Biology

In plant biology, regeneration is the process of renewal, restoration, and growth that makes cells, organisms, and ecosystems resilient to natural fluctuations or events that cause disturbance or damage. Regeneration is different from reproduction as it does not involve any sex cells to give rise to new plant. The branches of many trees, for example, can be cut off and in due course, sprouts appear at the margins of the stump and go on to develop new stems, leaves, and flowers.

3.2 Medicine

Regenerative medicine: Regenerative medicine is the branch of medicine that develops methods to regrow, repair or replace damaged or diseased cells, organs or tissues. Regenerative medicine includes the generation and use of therapeutic stem cells, tissue engineering and the production of artificial organs. Similar to the case in plants, regenerative medicine is to be distinguished from reproductive medicine which covers topics related to sex and fertility

3.3 Business

According to Carol Sanford, "… Regeneration is a process by which people, institutions, and materials evolve the capacity to fulfill their inherent potential in a world that is constantly changing around them. This can only be accomplished by going back to their roots, their origins, or their founding to discover what is truly singular or essential about them, [and bringing forward this essential core] in order to express it as new capacity and relevance" [7]. We noted earlier that innovation is often disruptive to process optimization. Thus, we would expect that regenerative businesses will be those that can exhibit an adaptive responsiveness to the environment in which they are situated using response to their output as feedback to pre-condition their input just like a Rankine cycle with regeneration.

From the foregoing, it can be seen that regeneration is a step beyond sustainability. Given the rapid disintegration of both our natural environment and lack of social mobility in a growing marginalized sector of our population, it is not enough to maintain the status quo. We must go further and develop systemic capacity for regeneration. How we do that will be the topic of the next section.

4. The Whole Systems Regenerative Cycle

One of the greatest challenges of any organization is learning to see the systems around it as a connected whole. Identifying patterns at nested scales helps create clarity around what's emerging, or "what wants to be." [7]. This is done by intentionally identifying and designing interventions aimed at nodes or acupressure points that restore health or unblock pathways that benefit the whole domain, not just isolated parts. When we intervene, we often introduce a new order, new capacity or innovation at these nodes, whether we are conscious of them or not.

To help us understand and act to evolve the capacity of individuals, teams, organizations, communities, and ecosystems, it is useful to identify common stages of development when working within these whole systems. The following areas of focus and attention, viewed as a continuous cycle of development, can help make sense of where we are intervening in the system with our initiatives and projects.

4.1 Sensing

The beginning of any initiative is enormously important. Once something is seeded and begins to grow its DNA expresses itself in every environment it touches. The process of discovering and intentionally optimizing for initial conditions begins by sensing – letting go of the past in order to connect with and learn from emerging future possibilities. This allows our circle of attention to widen and makes room for a new reality to enter the horizon that comes to fruition with conscious design aimed at critical nodes. Design allows us to be intentional, anticipatory, and aspirational, and to nurture the essence of the people bringing that future state into existence. By focusing time and attention on this stage of development, we can ensure that our strategies, initiatives, programs and so on, take full advantage of the opportunities before us. Yet progress cannot happen without authentic engagement with others.

4.2 Engagement

To "engage" means to attract or involve someone's attention; to participate or be involved in something. The authentic nature and potential of that involvement is greatly deepened when it is accompanied by support for the growth of each stakeholder involved. This means supporting the development of the individual, team, organization, community or ecosystem being engaged, and allowing all to evolve their potential through the work, in response to the opportunities being revealed.

4.3 Learning

As the inner and outer environment changes, it is important to introduce interventions that substantially improves on established conditions. Interventions within environments of increasing complexity requires new approaches which can be characterized by three factors: (1) Integrity – working from "the essence" of the domain being entered to identify highest potential opportunity at individual, structural and systemic levels. (2) Inclusion, a process of assimilation and accommodation [8] – exploring the edges of the new environment from many vantage points allows for new ways to see the whole and more angles into development that substantially improve on established conditions. (3) Diversity, through close interaction in a zone of proximal development [9] and transference [10] – the diversity of perspectives and experiences, allows for accelerated development.

4.4 Working (with feedback and feedforward)

As stated earlier, regeneration is a process by which people and organizations evolve their potential to improve on existing conditions in a world of rapid change. This happens by going back to the roots, origins, or founding in order to discover what is truly singular or essential about them. By bringing this essential core forward it is possible to express it as a new capacity with relevance. Where this is no longer possible it naturally ends. The crucial activity in this stage is to share learning about what happened, what worked, what failed, what remains essential, and what can be sloughed off [7]. This sharing is the new form of work. It leads to the rebirth or end of the initiatives in focus. It is here that our current dominant value system is challenged. Specifically, our current system can be summed up in the following dictum:

> Each man for hymself, ther is noon oother. Ref: "The Knight's Tale" by Geoffrey Chaucer (~1343–1400) [11].
>
> Each man for himself, there is no other [way].

This has been interpreted to mean that if a part of the system is failing, as long as one does not consider it to be one's own part, it is best left alone.

This dictum, can be considered in contrast to another dictum:

> Unus pro omnibus, omnes pro uno. (Latin)
>
> Un pour tous, tous pour un. (French)
>
> One for all, all for one. Ref: The Three Musketeers by Alexandre Dumas (1802–1870) [12]

This dictum can perhaps be better understood in light of a letter read by a protestant representative in 1618. The specific circumstances are often referred to as the defenestration of Prague. It reads in part:

> ". . . As they also absolutely intended to proceed with the execution against us, we came to a unanimous agreement among ourselves that, regardless of any loss of life and limb, honor and property, we would stand firm, with all for one and one for all . . . nor would we be subservient, but rather we would loyally help and protect each other to the utmost, against all difficulties." [13]

We have quoted this portion because earlier, we described the process of regeneration as ". . . happens by going back to the roots, origins, or founding – to discover what is truly singular or essential about them" [7]. Bearing this in mind, let us now look at the case study of SnapIT, as described by our co-author Neelima. Rather than convert her writing into a third-person observer voice, we have left it in the original form in which she wrote it. This way we hope to show some congruence between her essence, some of which we can glimpse from her writing, and the evidence. The evidence being the outcome of her actions.

5. Case Study: The SnapIT

SnapIT Solutions is a technology services and solutions company that has four primary lines of business: SnapIT Solves, SnapIT Pods, SnapIT Probes, and SnapIT Trains. Together they are known as the SnapIT SPRNT.

Let's start at the beginning.

5.1 SENSING

SnapIT Probes. The idea for SnapIT's business model took deeper and more meaningful roots with our co-author, Neelima, after a day spent mentoring at Society of Women Engineers "Introduce a Girl to Engineering Day" event. When she asked the students what other software engineers they knew as mentors, family or community members they said, 'Nobody.' Undaunted, she talked to them about her own career path and the scarcity of mentors in her life that were women engineers, and explained to them that the lack of women engineer mentors did not stop her path to become an engineer although having a Dad who is an engineer helped tremendously, as he was her first mentor. There were 5 girls that were matched to her and she had all day to spend with them. They got to know a little bit of each engineering industry by going through the industry and career fairs designed by career and industry professionals exhibiting their engineering products.

Most of the girls were actively engaged and asked questions. She was happy to note that they were able to gain more knowledge about engineering. There was one girl in particular that was reserved and had engaged much less with her (Neelima), and the rest of the team. But when she did engage, she had much more content and thought in her questions than the others in the group. Clearly, she was a bright girl but could not express herself more confidently within the group. When Neelima ended that day, she gave each of them her business card and told the girls to email or call if they needed any assistance in finding internships or other events. The girl who remained reserved sent her a text to thank her, saying, "You inspired me to be an engineer." Neelima said, that message felt more satisfying than she had felt the entire year at work. This feeling was the first seed of the idea for her model within SnapIT.

This exposure to youths who were clearly good logical and analytical thinkers and who also showed problem solving abilities, but did not have the constant exposure to relevant mentors, weighed heavily on Neelima's mind. In these youths she could see the great potential of her future employees. She felt that when given the right education and access to the appropriate mentors, they would have the same chances as suburban youths whose schools have better funding, and who have the additional support from their family and community. However, in order to train these students, it would cost her company, and even if she could find ways to fund the trainings for at least a few of these youths, her challenge would be how to reach out to them. It was then that she started actively engaging in Digital Inclusion efforts in Kansas City, and she began understanding the many challenges these youths and their families face.

Some of the challenges pertaining to technology education include: lack of access to the internet, inability to own a computer or a laptop, and schools with a lack of awareness of the changes in technology. Furthermore, very few schools offered credits to students who take time to learn Information Technology. In addition, most of these students do not have the financial support to attend a four-year college or university for a degree in Computer Sciences. Some may have to work while they are still in school to support themselves. None of the youth's parents had occupations in the IT field and it seemed like the less a student knew about IT, the stronger he or she desired to gain knowledge in IT as 'Screen Time' or 'Exposure to Social Media'. Access to the internet is still not accepted as a basic commodity, and access to a device (Desktop Computer or Laptop) was, for some of these youths, only at the public library – many did not even have access at school. It all seemed to be a deeper-rooted problem than she had first anticipated. The more she learned, the more she knew her task at hand would not be easy.

There are organizations that understand the importance of STEM careers and had access to youths but had challenges in finding the right Trainers to provide industry in-demand IT skills. Most minorities and girls were not choosing programming basics as their pathway to a career as they were only exposed to what they called 'coding classes' however, not every job in IT is in a coding/developer role.

5.2 ENGAGING

SnapIT Trains. Further researching and surveying the local resources, Neelima finally found the right organization, Full Employment Council (FEC) in Kansas City Missouri, that could possibly solve most of the issues mentioned. FEC is a non-profit corporation whose mission is to obtain public and private sector employment for the unemployed and the under-employed residents of the Greater Kansas City area. Her first meeting with their executive officer Shelley Penn, was mainly focused on what the different phases of Software Development Life Cycle are and how these students in Kansas City could benefit from learning these skills for various job roles without having a four-year degree.

Students from traditionally underrepresented and underserved communities are enrolled into fully funded Technology training programs by organizations that receive federal grants for workforce development. The students come from all walks of life, youth and young adults between the ages of 17 and 23, students who were at jobs that they took a break from in order to have a chance to enter IT, students who had just graduated from high-school, a few who had gone through a Bachelors' degree program in non-technology areas, and were looking to switch to IT and a few that had been in the IT industry for years and lost their jobs or some who were currently in jobs but had not been given the opportunity to get trained within their company. They all had the opportunity to attend these courses which were conducted during weekdays after regular office hours.

Fig. 2, shows a general model of education and simplified career path, whereby some youths and professionals for the various reasons mentioned are unable to fulfill their dreams and potential, in particular those that wish to pursue careers in IT. These have been shown in thick borders.

The first class was conducted at the FEC campus building with Rama Midigudla, the first employee of SnapIT, who delivered the course material to these students for a period of three months. The material was custom developed by SnapIT for specific languages based on Industry demand, and the course also included the 'soft skills' portion in Professional Development and Resume building taught by University of Central Missouri. FEC has multiple offices through 5 major counties within Missouri and they dedicate their staff to recruit students to these courses and once they have enough students enrolled for a class then engage SnapIT to conduct the IT Trainings via University of Central Missouri to FEC supported students.

When Rama started teaching the students, it was soon discovered that the communication about the technical syntax had to be in more common day-to-day terminology. For example, when he asked the students to give him a command to "Write on the board" and the students said "pick up the marker" now "walk to the board" and "write" he would write with the cap closed and then the students were like isn't it understood that you have to open the cap? When they realized that opening the cap is also a command and if they don't specify this, the computer will not understand. There were also times he would walk towards students and suddenly fall to the floor to show what happens to a process when an 'exception' happens when compiling a piece of code.

When hiring their Senior IT resources, SnapIT looks for training that includes both fun and engaging ways, as well as personal passion to impact and motivate their students willing to learn this difficult but rewarding skill. Not every senior employee is a trainer but almost all the trainers are also professionals who have a passion to teach in the subject that they have mastery in, and have been certified by Oracle, Microsoft, Hadoop, or hold a Masters' degree in Computer Science. Fig. 3 shows the very important role of the producer-teacher within the workplace. In the past, most career tracks in industry were split between a management track and a technical track. The teaching track is more common in teaching hospitals, where MD, PhDs are teaching regular students who have come in through the traditional route.

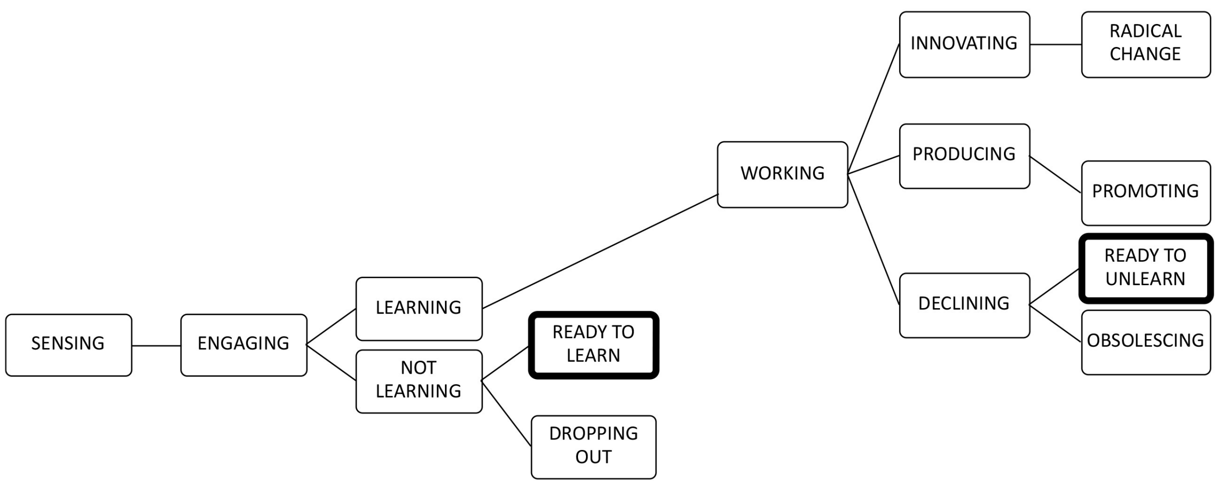

Fig. 2. A general model of education and simplified career path, whereby some youths and professionals – shown in thick borders are unable to fulfill their dreams and work aspirations.

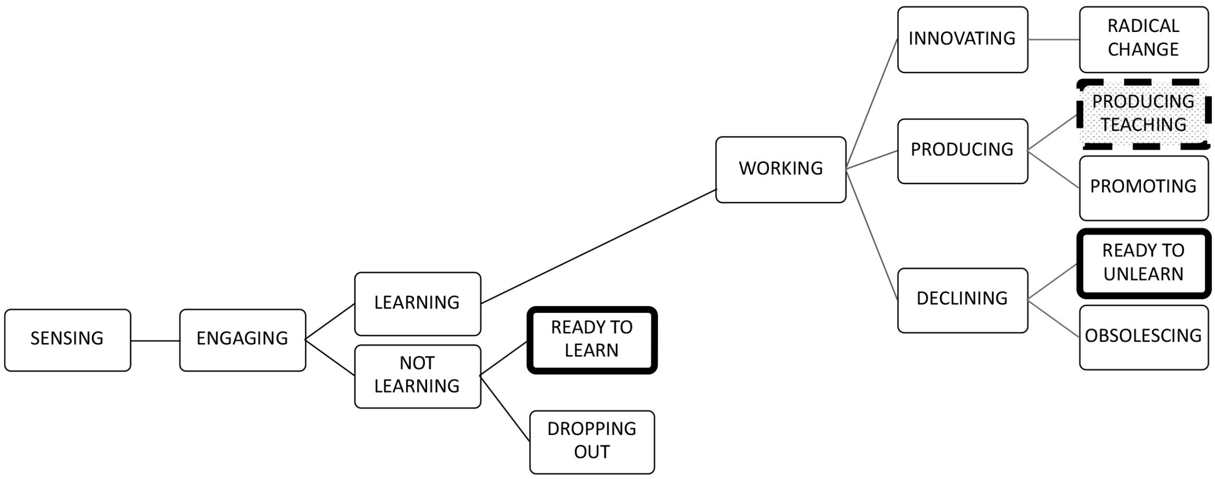

Fig. 3. A general model of education and simplified career path, showing the very important role of the producer-teacher (in thick dotted lines) within the workplace.

Over the last couple of years in which SnapIT has been providing the trainings, the material has been re-visited and fine-tuned to identify which areas to expand further and how the material will be delivered to result in much higher level of success at graduation and of student self-confidence. The company also continuously evaluates the success of the students in grasping the material. Students are also required to work on a final project and are encouraged to work in groups, but some of them prefer to work individually. During the last week of the course the students present their project to Industry professionals who judge their products and provide detailed feedback on every aspect of their work. This gives the students an understanding of the expected quality of their work product and feedback on what was taught from another professional's point of view. All training courses start with a self-assessment of where the students were when starting the course and end with a self-assessment of where they are at after the course material is delivered.

After the course is completed, FEC facilitates speed interviews for the students and invites local Small, Medium and Major corporations that have IT needs to attend, connect with, and interview the students. After the interview the students and employers are then given an option to prioritize their preferences. The students who received funding to take these courses are then provided an additional 8 weeks of paid internships from FEC, so that their work is at no cost to the company. Some interns are also hosted by SnapIT. During these internships the students work on enhancing SnapIT internal applications that help interns to learn more on the different phases of software development life cycle. Examples of this includes: Analysis of requirements, Design of the product, Development of the code, Testing of software changes made, and Deploying these changes into Github and Gitlabs. About 90% of Interns successfully complete the internship and after this SnapIT has a choice to bring these interns on board as their employees based on the demand of the projects coming into their pipeline. Once the interns are hired into SnapIT, they are offered paid apprenticeship positions. The work at SnapIT consists of internal design projects, SnapIT Solves, and external consulting project SnapIT pods. Each provides an apprenticeship in real world IT projects, and each has its pros and cons. We will discuss each in turn.

5.3 *LEARNING-by-doing*

SnapIT Solves: In this segment of the company, SnapIT is hired by established businesses from various industries that have need of a software product (web or mobile application) to help automate their current process or develop a software product that is designed by industry professionals who have a better grasp on their needs. When developing a software product for these industries, the initial phase to create a Most Viable Product will be mainly handled by seniors within SnapIT and offshore resources. SnapIT then engages their apprentices and junior resources to work on enhancing features for these products. This helps the junior resources implement their acquired design, code and testing skills on client facing projects with close mentoring from their senior lead. Daily standups are done within the teams and any roadblocks and/or delays are communicated to their team and scrum master on a daily basis. This process helps the SnapIT team to keep the ability to monitor and strengthen the skills of resources within the team.

While the seniors are tasked to lead hard skills training with the junior resources, some of the juniors are tasked to lead the team with other areas of improvement, such as measuring success via gathering statistics of the work performed and monitoring the apprentice's progress. This gives the juniors a sense of responsibility for the team's activities and enables them to interact with others on a regular basis. This has proven to build more interpersonal skills and comradery.

In the SnapIT Solves segment of the company, the products are built with an approach similar to 'design thinking' as the underlying concept of this phase is to truly create products that emphasize the user/client experience.

While working on creating customized technology products for market gap challenges, the SnapIT team also constantly assesses the skills progress of the junior resources and analyzes which job roles within SDLC (Software Development Life Cycle) as well as what areas of development, such as front-end, back-end or database skills are a better fit for the resource. This approach not only gives effective and affordable software to Small and Medium businesses needing IT solutions, but also gives a platform for the resources to grow their skills in a conducive work environment where there is lesser stress on timeline and other mainstream Tech industry challenges.

5.4 WORKING-by-belonging

SnapIT Pods: The motive behind the design of this part of the company stems from the fact that a well-trained and mentored individual from non-traditional background will still face the hurdle of the current hiring process due to not having a formal bachelor's degree in Computer Science and/or two or more years of relevant industry experience. SnapIT inducts these talented students who went through the intense IT trainings, and successfully completed an in-depth internship to work on client facing projects during apprenticeship into SnapIT Pods.

The pod team members typically tackle a chunk of work from a major corporation that is scoped out for them to work on usually for the period of a quarter. These pods consist of 4–6 members. A SnapIT pod will at minimum consists of at least an experienced senior lead developer who is willing to lead a group of developers with varied skill talent level, and a developer who can work independently with two or three junior developers. The work usually consists of enhancing already existing client applications – web and mobile – with new features.

On average, the cost of these pods is below market-value and they work to deliver skills that are high in-demand such as Java, JavaScript, React, Node, Ruby on Rails, C#, Android and IOS Mobile app development and other roles such as Quality Assurance and Project Coordination/Management. The work performed by these pods is low risk to the client, as the payment will only be made to SnapIT once the monthly milestones are met as per their agreement. This, however, is the high-risk aspect of the Model for SnapIT, as the estimation of work and scope changes have to be closely managed and any work delay would cause payment delays to SnapIT but the costs of the apprentice will still continue to hit SnapIT payroll budget. Since the resources working in these pods are conducting the work within SnapIT premises with occasional work at client site, it helps SnapIT continue to closely monitor their progress and engage them in continued training as and when needed.

An important advantage of this service is that it offers a three-way win for the apprentice, for SnapIT, and for the client. SnapIT is able to produce the work for major corporation as a valued partner and gains knowledge of the future pipeline of projects in clients forecast. SnapIT team can prepare for the requirement well ahead and prepare the resources for the client's upcoming demands. After a couple years of work experience, this process would allow SnapIT and the Client to evaluate the employee's work and give the employee an opportunity to pick between continuing with SnapIT or moving to Clients company with a standard fee agreement per the market standards.

In addition to the employment opportunities, and technology training, the apprentices are also nurtured in other areas of professional development that include financial education and gaining access to closed discussions with industry experts that visit SnapIT and share their insights of the industry and trends of the technology. These pods have well balanced knowledge sharing opportunities not only within the pod, but across pods to keep adding more skills to their portfolio.

As mentioned earlier, the only major disadvantage of the SnapIT pods idea is the need to estimate the scope of work appropriately to avoid delays, extended work hours and missed timelines. If the apprentice is not yet ready to be put in a pod then the work that needs to be performed will be impacted. Some students give up or get distracted as the path to this intense training and mentoring is daunting and extremely demanding.

In Fig. 4, we show a model of the regular learning model for the traditional student and in Fig. 5, we show the regenerative learning model for the challenged student.

5.5 Process Summary

The following is a summary of the current process.

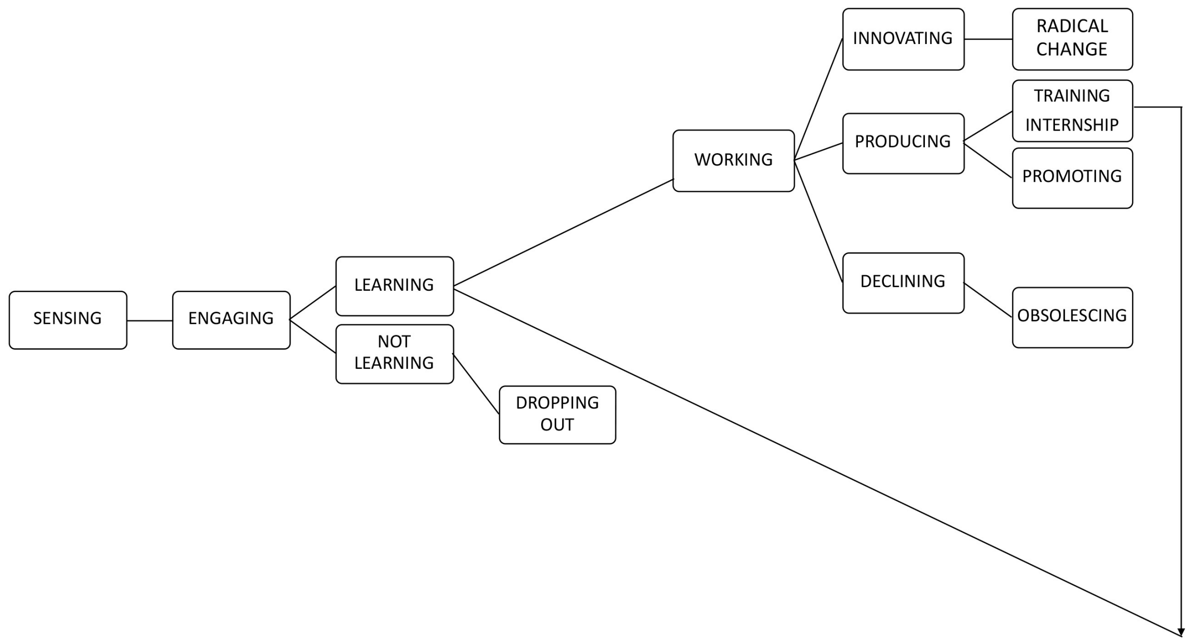

Fig. 4. The regular school to learning model for the traditional student.

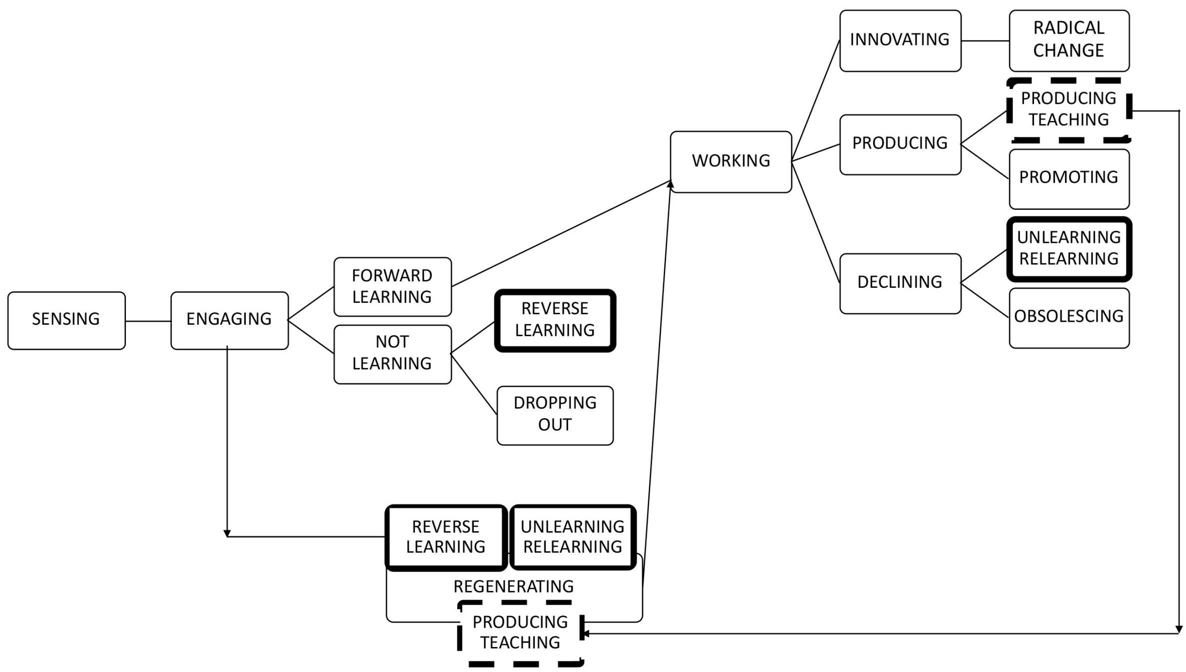

Fig. 5. The regenerative learning model for the challenged student.

Pre-SnapIT State: Novices. These are often students that have no financial backing to go to a four-year degree program or lost their job in a current non-IT or IT field. In addition, they could be students who have passed High-school and cannot afford the cost and time required for any other traditional training programs which typically last from one to two years at the minimum. Fig. 6, shows the progression from this starting state through the various steps for the novice in the SnapIT SPRNT process

SnapIT Probes Step 1: This is the equivalent of SnapIT's outreach program where Neelima spent a day mentoring at the Society of Women Engineers "Introduce a Girl to Engineering Day" event.

SnapIT Trains Step 2: This phase of the process is finding the best way to 'enter' for the above students by overcoming the barriers to entry. Through partnership efforts between FEC and SnapIT, students are given a short but intense course on a specific in-demand-skills in IT (Java, JavaScript, Angular, C#, and project management skills).

Fig. 6. A simple linear representation of the movement of the novice through the Regenerative Learning Cycle

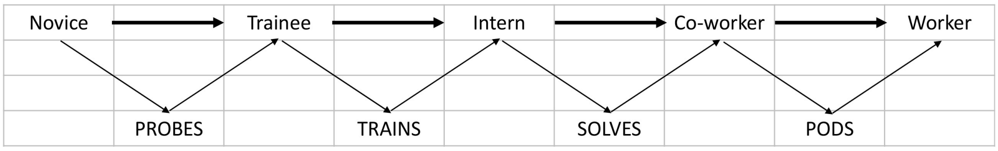

Fig. 7. A simple representation of the movement of the novice through the regenerative cycle in relation to a simplified representation of the SnapIT SPRNT business model for regenerative learning.

These trainings are conducted by IT professionals who have been in the industry as developers and/or earned the relevant certificates to conduct the trainings. 100% of these training are currently conducted for students who are eligible for federal or other grants through Full Employment Council and all the students are eligible to receive 100% tuition reimbursement. The students spend three months immersed in an IT training curriculum custom developed by SnapIT.

SnapIT Solves Step 3: In this phase of the process, students are exposed to potential local Tech employers including SnapIT leads. The SnapIT team lead (who was not the student's trainer) interviews the students from the class. If approved for internship with SnapIT, the students are offered positions to further enhance the skills they learned by working on real world projects that are developed internally by SnapIT. For two months they apply the new skills while they are paid to work as Interns for SnapIT, at this stage they are on Federally sponsored internships. During this stage the interns are exposed to many personal and professional skills and taught various development and delivery methodologies, and also how to give constructive feedback and teamwork. In the middle of this phase, SnapIT is given a choice to hire the interns full time into the company. The decision is based on the internal workload of the company and its belief in its ability to further develop the individual, as well as the choice of the intern. Those that are selected and accept the SnapIT offer are hired into SnapIT as apprentices, where they work on small scale, in-house projects, so that the SnapIT lead team can personally oversee their growth.

SnapIT Pods Step 4: In the final phase of the program, each trainee is placed in a SnapIT "Pod" consisting of two experienced Senior Associates working with about three Junior Associates. These Pods are then given scope of work from IT project to complete, with monthly milestones. This is crucial for SnapIT, as the company is only paid when the scope of work that is agreed upon by Client and SnapIT is met to the client's standards. The learning for employees is a constant as for the next couple years the junior associates are learning while getting paid, but given tasks that are appropriate for their skill level. There are several of the junior associates that catch up and perform alongside the senior employees within 1.5 to 2 years. If not for this process about 60% of SnapIT employees would not have ended in an IT career jobs. Fig. 7 shows a simple representation of the SnapIT SPRNT process in relation to the transformation of the novice, and Fig. 8 shows how the regeneration process is built into every step in the SPRNT process. The process can be thought of as an ascending spiral or helix, as each step builds on top of the previous step like a screw.

5.6 Results to Date

SnapIT started with the goal of helping to change at least 10 young adults' lives each year with the model. In 2018, 80+ students were trained and SnapIT was able to hire 12+ of them as full-time resources. In 2019, they are on track to train at least 350 plus students just in the state of Missouri, and have plans to train students in other states as well. Most of these students have not been exposed to basic IT programming skills in schools or other sources of secondary education. Although this has been one of the biggest challenges to slow the progress of the students that join the courses, there are a good number of them that are doing exceptionally well in the 6–9 months they have been engaged in the process. The data show that 80% of the students graduate from the training by keeping their attendance through the course duration, and 70% of them land in Internships with various companies. There is diversity in the number of people going through these trainings, for example, more women are able to take these short duration trainings in comparison to regular 4-year degree programs due to tuition aid and support for other expenses such as transportation and child support where eligible.

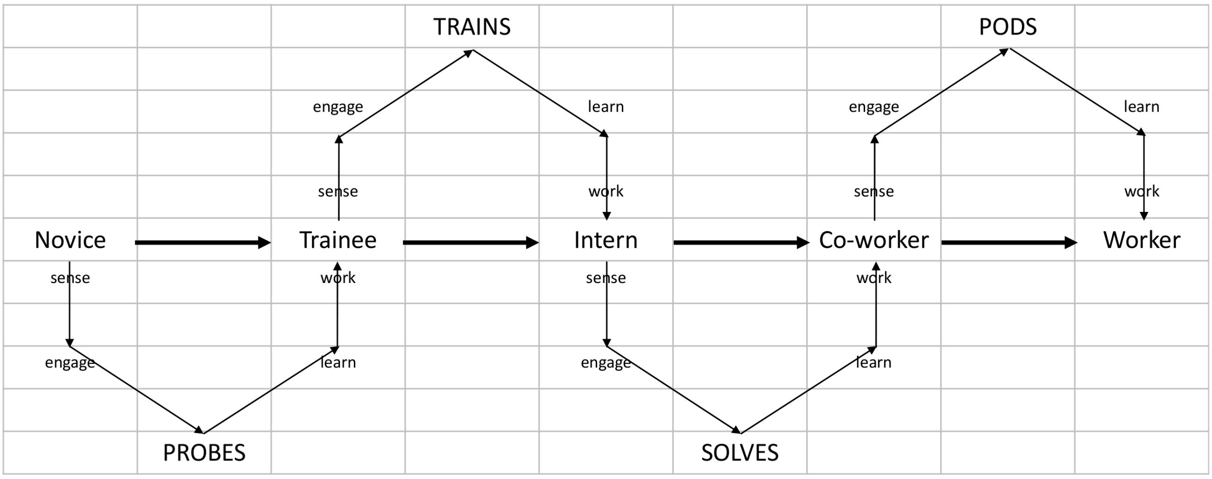

Fig. 8. A simple representation of the movement of the novice through the regenerative cycle in relation to a more explicit and detailed representation of the SnapIT SPRNT business model for regenerative learning. Note that the regenerative learning cycle occurs in each business model unit, and the totality would be helical in nature.

Students are provided with books and tablets so they can continue education beyond the classroom and given sources for online free or low-cost training sources.

All interns are paid above the minimum wage salary and some of these students who graduated from the first class in 2017 have completed 3rd party certifications such as Oracle Certified Java Developers, JavaScript Certified by NCSA, Python Programmer Certified by PCAP. A few of them took courses to become certified to train other students into these courses within SnapIT. Most of them are developers who go on to learn more than one coding language within the first year. Currently the job roles that can be targeted with these trainings are Developer for various object-oriented programming languages, Web Designer, Software Tester, Project Coordinator or Project Manager roles. Plans are in motion to provide training that target Cyber Security, Data Analyst and Business Analyst for Cloud etc.

Thus, this regenerative model has helped to create the IT talent with diverse background from segments of the current population that have been neglected or ignored either due to financial incapability of the student or the rigidity of the work environment rather than their inability to gain the knowledge needed.

6. Observations and Discussions

First, observe that we are working with two disruptions here. First the disruption to the disadvantaged person's education, for whatever reason. Second, the disruption in the Economy caused by the shift to Information Technology. Thus, the second disruption created an opportunity to counter the first disruption and promote a form of regeneration. In this period of rapid transition to a digital economy, as well as impending disruptions that will be caused by global climate change, we anticipate that there will be an increasing need for regenerative models such as has been presented here.

Second, observe the heterogeneity of the work and the ability to match students to areas of their strength very early in their engagement. While typical school learning tends to be uniform, and leads to increased disengagement rates [14], the tailored approach above recognizes and invests in the value of individual interests with potential for higher rates of retention and productivity. As Neelima stated earlier, most minorities and girls were not choosing programming basics as their pathway to a career as they were only exposed to what they called 'coding classes.' However, not every job in IT is in a coding job. As interns they were exposed early to different phases of the software development life cycle, such as Requirements Analysis, Software architecture, Code Development, Software Testing, and User testing.

Third, at the core of the program are the first two steps, sensing and engaging, empathizing with and acting in a positive way on behalf of another. This was the motivation for Neelima, and the results to date bear witness to the power of such motivation. As noted earlier, this motivation belongs to an earlier value system captured by the dictum – Unus pro omnibus, omnes pro uno – "one for all, all for one." Neelima in a sense identified with the situation of the young girls and with a bias towards action, undertook to develop this system which coincided with the idea of Whole Systems Regenerative Learning. Her approach seems to stand in contrast to a trend the political scientist Francis

Fukuyama identified in a recent book [15]. He wrote:

> "Institutions are the rules that coordinate social behavior. Just as tribes are based on the deep-seated human instinct of looking out for one's family and relatives, states depend on the human propensity to create and follow social rules."

Reflecting on this quote brings us back to the beginning of this paper. In particular we will requote at length from three paragraphs. We wrote:

> ". . . While the industrial age powered by mechanization has given us the ability to create and distribute almost any product or service at scale to large sectors of the human population. It is worthwhile to note that this development has come at the expense of damage to the Earth's climate and at the expense of many who have been marginalized and left without secure access to basic needs. The industrial era arose from a Newtonian understanding of reality where everything can be broken into fragmented component parts. Specialization, assembly lines, hierarchical organizational charts, the time clock all allowed us to systemize production, to break down our goals and translate them into component tasks and processes. At the same time, we shifted the purpose of education from helping people lift themselves up to training people to work in the industrial production system."
>
> "The idea for SnapIT's business model took deeper and more meaningful roots with our co-author, Neelima, after a day spent mentoring at Society of Women Engineers "Introduce a Girl to Engineering Day" event. . . . When she asked the students what other software engineers they knew as mentors, family or community members they said, 'Nobody.' . . . The girl who remained reserved sent her a text to thank her, saying, "You inspired me to be an engineer." Neelima said, that message felt more satisfying than she had felt the entire year at work. This feeling was the first seed of the idea for her model within SnapIT."
>
> ". . . Quantum theory posits that everything is connected, compelling a much more holistic view of reality. Fluid socio-cultural environments that overlap and intertwine, sometimes visible, sometimes not. Waves of change that rise and fall like a sea of organisms that self-organize themselves in response to the environment. This would be analogous to individuals in open meaningful dialogue across silos allowing each to see a larger, more complex picture of their own environment. It is our contention that in order for our contemporary socio-economic systems to serve humanity in the current era, they must mirror our contemporary scientific paradigm, in the same way our industrial age systems mirrored the dominant scientific paradigm of its time. In doing so we have the possibility to find paths of least resistance and an underlying integrity to underpin a new operating system at nested scales – as individuals, as teams, as communities as regions, as a planet."

In reflecting on these paragraphs, we could not help but observe that Neelima's response differed from Fukuyama's description of states and tribes. States created rule-following beings and tribes created filially pious beings. How could we explain Neelima's instinct, and drive, for regeneration? We do not know for sure – as it could be biographical, situational, and/or cultural. These questions are important to us, because from an engineering viewpoint, we believe the sourcing, controlling, and dissipation of energy, material and cultural, could explain a lot of the behaviors we observe. In the course of our research we came across the work of Jocelyn Marrow, an anthropologist working in Northern India. Before going on to describe her findings, it is important to point out that Neelima is not from Northern India, and we are introducing this literature to enable us to broaden the range of concepts we could use to explain and/or reverse engineer the impact Neelima has had on the technologically disenfranchised youths in her community.

> ". . . Some questions motivating my research with North Indian families are: What is the range of expected communicative responses to expressions of emotional distress? How might sensitivity, sympathy, empathy, and succor be expressed and experienced among adults in intimate North Indian settings, and how do these expressions and experiences expand scholarly understanding of interpersonal communication, emotion, and psychological functioning in general? I discovered that persons spoke about managing the feelings, self-expression, and behaviors of others in distinctive ways. According to the cultural theory, persons 'cause' others 'to understand' (samjhaana) – that is, they provide explicit instruction and exhortation regarding the most effective or morally correct behaviors and attitudes pertaining to specific contexts. Overt attempts at emotion work tend to flow down intimate hierarchies of generation, age, and gender. The cultural theory of 'causing understanding' holds that hierarchical seniors expect that their subordinates, once exhorted, will conform to their prescriptions in return for emotional rewards, particularly the expressions of seniors' love towards them. The 'loving' emotional rewards that juniors receive in return for 'understanding' include the experience of being assimilated to the wisdom and moral qualities of the elder – an experience of positive merger with the elder . . . My basic claim is that this asymmetrical model of empathy among North Indians arises from a distinctive North Indian theory of mind in which minds/bodies possess essential differences that are highly susceptible to contamination, contagion, and impression through contact with others. According to this model, minds are continuously constituted and reconstituted through interaction with others. Other persons may contribute to a refinement and improvement of an individual's mind if their speech and interactions with the individual are true and moral" [16].

In the thermodynamics of regeneration, increasing the efficiency of steam power cycle is done by extracting some of the steam from the turbine and using it to preheat the compressed liquid before it enters the boiler. This is done either by direct mixing of the fluids (Open Feedwater Heater) or through a heat exchanger (Closed Feedwater Heater). The genesis of the SnapIT system is comparable to an open feedwater heater. The process whereby minds are continuously constituted and reconstituted through interaction with others could offer us one of the pathways towards evolving a new human operating system in the information age.

The fourth observation is a detour, a movement back to the context of our paper, and a break from a linear writing, and the reader is appropriately cautioned. This final observation is one of serendipity and is best considered as a happy coincidence. Our goal as explained at the beginning was to explore the correspondence between the thermodynamic regeneration process and the SnapIT process Neelima had created and developed. We believe we have demonstrated this correspondence. At the same time, we wanted Neelima to describe what she had done or thought she had done, independent of our goals. In this way we would have a sense of the error between Neelima's conception of her process and our artificially imposed proxy – the ideal Rankine cycle with regeneration.

So, we asked Neelima to *draw* her process. This request was also motivated by the fact that Neelima kept talking and gesturing about a spiral but never expressed it diagrammatically. Her response to our request is shown in Fig. 9a. Our interpretation of Fig. 9a is what we presented in Fig. 8.

While Neelima was satisfied with the correspondence between the two representations i.e., Fig. 9a and Fig. 8, we remembered that several years ago, Nonaka and Takeuchi wrote a book titled – The Knowledge Creating Company [17], where they described the way they had observed Japanese companies create knowledge. In the book, they built on Polanyi's distinction between two types of knowledge – tacit knowledge and explicit knowledge – to present their SECI model of the knowledge creation process consisting of four steps: externalization, a movement from tacit to explicit; combination, a movement from explicit to explicit; internalization, a movement from explicit to tacit; and socialization, a movement from tacit to tacit. This process is shown besides Neelima's diagram in Fig. 9b. Notice that they both have a spiral and they both have a way to talk about the growth of knowledge. In the case of Neelima she talks about "learning" and in the case of Nonaka and Takeuchi, they talk about "knowledge creation." For now, we will assume a relationship exists between learning and knowledge creation, because Nonaka and Takeuchi made an additional and important contribution to the field of knowledge management. They wrote:

> "To understand the difference [between the intellectual traditions of Western Culture and Japanese Culture], we need to examine fundamental assumptions about what knowledge is and how knowledge comes about. The philosophical inquiry of knowledge is known as 'epistemology.' While there is a rich epistemological tradition in Western philosophy, there is almost none to speak of in Japan. Yet this is in itself a reflection of the very different ways that the two cultures think about knowledge. In Western philosophy there has been a tradition separating the subject who knows from the object that is known. This tradition was given a solid methodological basis by Descartes, who posited the 'Cartesian split' between subject (the knower) and object (the known), mind and body, or mind and matter . . . The most important characteristic of Japanese thinking can be termed a 'oneness of humanity and nature.' . . . According to this tradition, the Japanese perception is oriented toward objects in nature that are subtle but, at the same time, visual and concrete. While Japanese epistemology has nurtured a delicate and sophisticated sensitivity of nature, it has prevented the objectification of nature and the development of sound skepticism. [It has been] argued that the Japanese had failed to build up rational thought of clear universality, because they did not succeed in the separation and objectification of self and nature" [17].

Thus, through the foregoing work on SnapIT and the contrast Nonaka and Takeuchi drew between

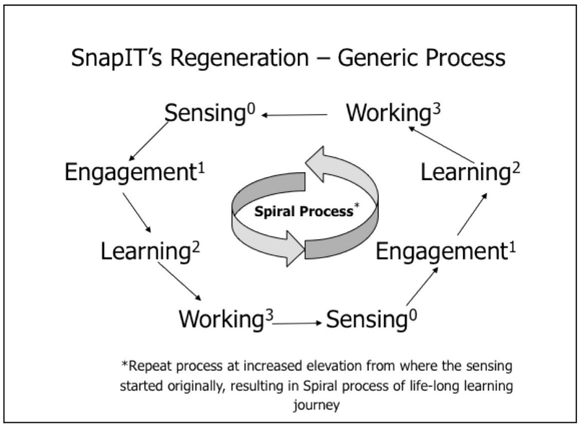

Fig. 9a. Neelima's representation of her process.

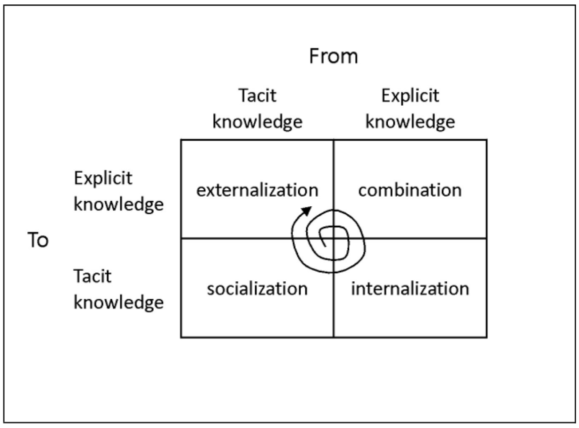

Fig. 9b. Nonaka and Takeuchi's SECI process. Knowledge spiral combined with the four modes of knowledge conversion.

Table 1. A provisional framework for understanding the potential contribution of various cultures and traditions to engineering learning and work processes.

	Type of Work Process	Outcome	Epistemological tradition based on Nonaka and Takeuchi's observation
1	Rational and Synthetical work	Power Generation	Western Engineering
2	Emotional and Verbal work	Emotion Regeneration	Indian Tradition
3	Physical (concrete) and Visual work	Knowledge Creation	Japanese Tradition
4	Analytical and Rhetorical work	Knowledge Discovery	Western Philosophy

the intellectual tradition of western culture and that of the Japanese culture, we can now compare and translate between tradition of four cultures – Western Philosophy (Cartesian split) Western Engineering (Thermodynamic Power Generation), Japanese Tradition (Visual, Concrete, Oneness of Humanity and Nature), and Indian Tradition (Emotion, Hierarchical, Flow of Interaction and Constitution of Mind). In essence, we have been attending to different types of "work". The reader may recall from part of the excerpt from Jocelyn Marrow's description of emotion work in Northern India: ". . . Overt attempts at emotion work tend to flow down intimate hierarchies of generation, age, and gender. The different types of work are summarized in Table 1.

7. Reflection and Meta-Discussion

One of the odd features of this paper is the pair of breaks from narrative linearity. Earlier on, we explained that our interest is in the process of innovation, and that these breaks mirrored the disruptions that were inherent in innovation. Further reflection however, helped us to see that as engineers, our processes do not follow the narrative arc which is norm of western rhetoric used in the art of persuasion. However, we were not as aware of this before our collaboration and writing this paper. While four of us are engineers, one of us is a lawyer. Amongst us Engineers, we have teachers, researchers, practitioners, leaders, and ethnographers.

Thus Figs. 10a and b – express some of the tension

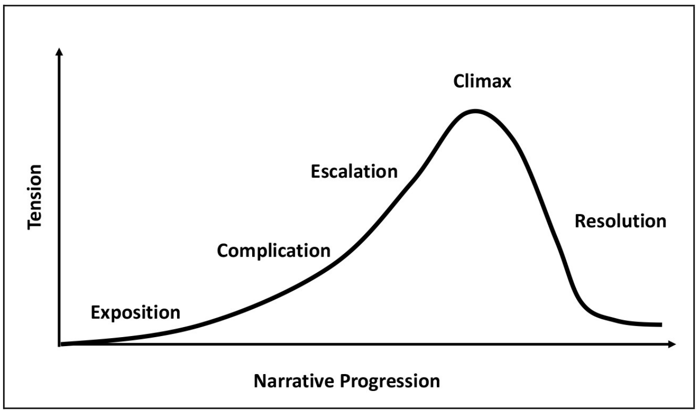

Fig. 10a. Western culture: rhetorical persuasion tradition.

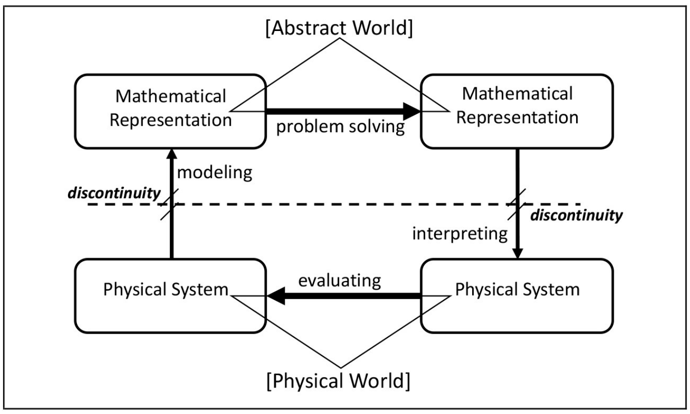

Fig. 10b. Engineering design culture: a situated functional mechanism mapping tradition [18–23].

we experienced as a group in writing the paper. The figures represent two different ways of solving problems. Before our collaboration we would have written in the rhetorical persuasion tradition. Now working with someone with a legal background, and competency in making rhetorically water-tight arguments, we realized as engineers, our world does not work in that manner. Our "arguments" are watertight so to speak, when we make assumptions such as processes being adiabatic, isothermal, or isentropic. These simplifications allow us to solve problems mathematically but not physically[3] [18–20] or by extension socially[4] [21– 23] without additional steps and approximations. The disruptions and discontinuities we have talked about are very much a part of our process. This experience was best described by Sunny Auyang in her book titled Engineering – An Endless Frontier [24]. Here she made the argument that most engineering theories were synthetic theories which had the following properties:

> "A synthetic theory, which brings knowledge from two sciences to bear on a single topic, is more than the sum of its parts, because it must introduce novel concepts to fill in the gaps, establish interfaces, and reconcile different approximations."

This is very much what we have tried to do in attempting a situated functional mechanism mapping between a people-based SnapIT process, and a fluid-based Rankine cycle. Just as the people in Snap-IT are situated within a community, the fluid in a power plant is situated within a given climate environment. Having done the mapping, we can now find ways to improve concepts such as process efficiency and effectiveness, and environment or community impact. For now, these are beyond the scope of this paper. It is worth noting that the situated functional mechanism mapping can be thought of like Gero and Kannengiesser's situated function behavior structure framework [25], with the additional concepts of energy, culture, and mapping. Another item of reflection for us, is that the mapping we have made is an approximation. However, once we develop the sense of a cycle in engineering, we understand how successive iterations can be used to improve performance. In this way, the concept of regenerative learning can be made to be more efficient, more effective, and more impactful.

[3] The salient point here is that artificial physical systems are situated within natural physical worlds.

[4] Similar to the above, artificial social systems are situated within natural social worlds. For more on this, see Albert Bandura's triadic model of reciprocal causation [21], and Douglass North's framework of transitions between social orders or worlds [22, 23].

8. Conclusion

In the beginning of the paper, we described "process" as ". . . both of two things. First, the sequence of activities to produce an effect, and that sequence can then be automated to produce the effect, sometimes at a larger scale. Second, the combination of resources to produce an artifact and that combination can then be automated to produce the artifact, sometimes at a larger scale." We then went on to compare the thermodynamic regeneration process, with the learning regeneration process we observed at SnapIT. This was summed up in the SnapIT SPRNT model. Based on the comparisons, we made several associative observations, grounded in the work practices at SnapIT Inc. These ultimately led to the uncovering of a conceptual working model between a regenerative process and culture. There is now a lot of theoretical ground to be covered, and so many questions that we can now ask about the relationship between process and culture. Specifically, we can look to culture, not just our own culture but different cultures as resources for coping with process disruptions caused by technological innovation and/or natural disasters. In addition, we believe having a testbed in Industry, such as SnapIT, will give us a way to operationalize the insights we gather from our work in order to improve and evolve a practice of regenerative learning in engineering.

References

1. D. Schon, Learning to Design and Designing to Learn, Nordisk Arkitekturforskning, *Nordic Journal of Architectural Research*, **1**, pp. 55–70, 1993.
2. M. Beam, *Integrity: The Search for Me in the Age of We*, Unpublished Manuscript.
3. World Economic Forum, https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ Accessed April 29, 2019.
4. D. Rushkoff, Present Shock, https://vimeo.com/91720717, Accessed April 29, 2019.
5. BankRate, https://www.bankrate.com/banking/savings/financial-security-0118/ Accessed April 29, 2019.
6. K. Gramoll and M. Huang, Multimedia Engineering Thermodynamics, https://www.ecourses.ou.edu/cgi-bin/ebook.cgi?doc=&topic=th&chap_sec=10.3&page=theory , Accessed on Jan 30, 2019.
7. C. Sanford, *The regenerative business: redesign work, cultivate human potential, achieve extraordinary outcomes*, Nicholas Brealey, New York, 2017.
8. J. Piaget, Piaget's theory. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. Vol.1 (3d ed.). New York: Wiley, pp 706–708, 1970.

9. L. S. Vygotsky, Interaction between learning and development (M. Lopez-Morillas, Trans.). In M. Cole, V. John-Steiner, S. Scribner and E. Souberman (Eds.), Mind in society: The development of higher psychological processes Cambridge, MA: Harvard University Press. pp. 79–91, 1978.
10. A. Wilson and L. Weinstein, The transference and the zone of proximal development, *Journal of the American Psychoanalytic Association*, **44**, pp. 167–200, 1996.
11. A Knight's Tale, by Geoffrey Chaucer (~1343–1400), https://sites.fas.harvard.edu/~chaucer/teachslf/kt-par1.htm Accessed April 29, 2019.
12. A Dumas, *The Three Musketeers*, Penguin Random House UK, 2008
13. T. Helfferich, *The Thirty Years War: A Documentary History*, Hackett Publishing Company, Indianapolis, p. 16, 2009.
14. R. Arum and R. J. Roksa, *Academically Adrift: Limited Learning on College Campuses*, Chicago, IL, University of Chicago Press, 2011.
15. F. Fukuyama, *The Origins of Political Order: From Prehuman Times to the French Revolution*, New York: Farrar, Straus and Giroux, 2011.
16. J. Marrow, The constitution of mind: What's in a mind? Selves, in Toward an Anthropological Theory of Mind, ed. Tanya Marie Luhrmann, Suomen_Antropologi, *Journal of the Finnish Anthropological Society*, **36**(4), pp. 21–23, 2011.
17. I. Nonaka and H. Takechi, *The knowledge creating company: How Japanese companies create the dynamics of innovation*, Oxford University Press, New York, NY, 1995.
18. W. J. Clancey, *Heuristic Classification, Artificial Intelligence*, **27**(3) pp. 289–350, 1985.
19. E. Redish, A theoretical framework for physics education research: Modeling student thinking, In E. F. Redish and M. Vicentini (Eds.), *Proceedings of the international school of physics 'Enrico Fermi', Varenna, Como Lake*, course clvi, pp. 1–65, 2004.
20. E. F. Redish, Problem solving and the use of math in physics courses. In Conference World View on Physics Education in 2005: Focusing on Change, Delhi, August 21–26, 2005.http://arxiv.org/abs/physics/0608268, accessed August 21, 2019.
21. A. Bandura, Personal and Collective Efficacy in Human Adaptation and Change. In: Adair, J. G., Belanger, D. and Dion, K. L., Eds., Advances in Psychological Science: Vol. 1. Personal, Social and Cultural Aspects, Hove, UK: Psychology Press, pp. 51–71, 1998.
22. D. C. North, J. J. Wallis and B. R. Weingast, The Natural State: The Political Economy of Non-Development, 2005, Los Angeles: University of California in Los Angeles, https://international.ucla.edu/institute/article/22899, accessed October 20, 2019.
23. D. C. North, J. J. Wallis and B. R. Weingast, *Violence and Social Orders: A Conceptual Framework for Interpreting Recorded Human History*, Cambridge: Cambridge University Press, 2012.
24. S. Y. Auyang, *Engineering – An Endless Frontier*, Cambridge: Harvard University Press, 2004.
25. J. S. Gero and N. Kannengiesser, The Situated Function-Behavior-Structure Framework, *Design Studies*, **25**(4) pp. 373–391, 2004.

Ade Mabogunje is a Senior Research Scientist at the Center for Design Research at Stanford University. He holds a PhD, MS and BS in Mechanical Engineering.

Neelima Parasker is the President and CEO of SnapIT Solutions. She holds a Bachelor of Engineering in Mechanical and Master of Science degree in Computer Science. In addition, she has a Project Management Professional (PMP®) Certificate from the Project Management Institute. She has 19 plus years of experience in IT and has held leadership positions in Fortune 500 Companies.

Mark Beam is the director of innovation and design in Entrepreneurship at the Ewing Marion Kauffman Foundation. He holds a Masters of Business Administration, and a Juris Doctor degree.

Neeraj Sonalkar is a Senior Research Engineer at the Center for Design Research at Stanford University. He holds a PhD, MS and BS in Mechanical Engineering.

Larry Leifer is a Professor in the Department of Mechanical Engineering at Stanford University. He holds a PhD in Biomedical Engineering, an MS in Product Design and a BS in Engineering Sciences.