RAIS RESEARCH ASSOCIATION for INTERDISCIPLINARY STUDIES
JUNE 2020

DOI: 10.5281/zenodo.3909863

Codified Ideas in Interdisciplinary Collaborations

Frank Lorne[1], Victor Zubashev[2]

[1]*New York Institute of Technology-Vancouver, Canada, florne@nyit.edu*
[2]*QBOT Technologies, Canada, Victor.Zubashev@gbotch.com*

ABSTRACT: The paper describes a process of meme evolutions in sequential time stages across different disciplines, approaches, and broadly speaking, paradigms. Idea creations between individuals are characterized as codified ideas that can be expanded or simplified according to implicit software used by individuals based on prior knowledge and experience. Neural networks of forms and layers involving input, output, recurrent, memory cells inside of a brain can be similarly conceptualized for communications across individuals for a better understanding of interdisciplinary collaborations. Codified ideas are assumed to be expressed in terms of symbols on the keyboards of computers, which require software to interpret as well as re-expressed to arrive at ideas that can be physically embodied. Different disciplines have different software. Ideas evolved from different software may or may not be physically embodied into something tangible. Tangible physical objects embodying ideas can be scaled or bundled to be branded and marketed. Evolution of memes in terms of codified ideas physically embodied precedes the forming of firms and markets. The emphasis on sequential time stages in the meme evolution in terms of codified ideas can fill a void towards a better understanding of how firms and markets operate. Several types of interdisciplinary collaborations can be identified based on this formulation.

KEYWORDS: communication, group creativity, idea embodiment, economic systems

Introduction

There has been much research done on the theory of firm, markets, and technological changes. Nobel prize winning writings on this subject have been numerous (Coase 1932, 1960; Williamson, 1975; Romer, 1990). An area not addressed too often have been the process leading to the forming of firms and institutions. Individuals cluster and interact. It is through a process of information dissemination that explicit institutional structures gradually can take its shape. This paper studies that process with a similarity as that described in studies of neural networks of brain cells interacting with each other in generating ideas. By defining information in terms of codified ideas, a variety of how ideas evolve into various meme evolutions prior to the forming of firms and markets can be identified.

To be sure, codified ideas in this paper are for illustrative purpose and does not mean abstract ideas can all be digitized for codification. Certainly, our illustration will not exhaust all circumstances for innovative collaborations. Creativity occur in many expressions, formats and media, e.g. artworks, music, lifestyles, etc, not all of them are in the form of codified ideas. The inquiry attempted in this paper is to assume a subset that can be codified, and indeed, codified in some specific way that could be insightful for understanding creativity arising from interdisciplinary collaborations.

In a broader context, we are hoping this illustration exercise will add credence to a debate started by economist's categorization of information as a public good (Sameulson 1954), applied explicitly in the context of information (Arrow 1962), debated with critical counter arguments (Demsetz 1969), and prophetically commented in the context of the information economy of 21st century (Rosa 2000, English edition 2006). Information as public goods need to be embedded into physical objects in order to be transferrable. Without physical embodiment, as products or as process, ideas are useful only as inputs for generating other ideas. Economists have developed many analytical tools for analysing physical products and process, e.g. supply, demand, production functions, etc. There have not been enough tools developed for analysing the nature of ideas evolvement in these functional specifications except that they are probabilistically evolutionary (Nelson and Winter 1985). The proposition of evolutionary economics certainly has stimulated many additional researches on the theory of firms, management theories in business schools, differentiating new approaches different from the nexus of contracts notion of firms (Kogut and

Zander 1992, 1996), as well as extending it in epistemic studies (Hakanson 2007, 2010). Other disciplines too, e.g. education (Baruah and Paulus 2019), sociology (Brown and Duguid 2001), psychology (Paulus, Baruah, Jonali, Kenworthy 2018; Thayer, Petruzzelli, McClurg 2018), all provided some frameworks for studying interdisciplinary collaboration for creativity. Likewise, numerous case studies across multiple disciplines have told successful stories of collaboration of research and the creation of knowledge.

Our study wants to create a framework for studying "what could have happened" rather than what had happened. The mere fact that many of the reference we are using for this study being joint authorship works is self-revealing in that collaborative work within and across disciplines have often happened. Our main focus is on a pre-firm and pre-institution setting, before creative work can be recognized in some physical forms. Section I describes the sequential time stages of ideas embedment. Section II elaborates on codified ideas that go through different transformations as meme evolution. Section III describes different interdisciplinary collaborations. We conclude by recapturing the emphasis and point out the limitation.

Section I: Ideas and Physical Embodiment—Sequential Time Stages

Idea creation is a cognitive function of our brain. Human's brain solving daily numerous problems reiterating past experiences with new concepts. On the individual level, people to people generating and reiterating ideas differently depending on unique neuropsychological development of the brain of a person. Communication between brains (i.e. between individuals) can be conceptualized based on communication inside a brain. The latter, the study of neural networks, can be similarly used for studying the evolution of memes between individuals. Economists would summarize what's going on inside the brain of an individual as "utility function", or broadly as preference, see Robson (2001). We are not taking this approach even though the evolutionary aspect of how innovative ideas evolve can be similar. We are more interested in analysing how individuals would collaboratively create ideas under different settings of cultures, exposures and environment. The communication framework as suggested in Shannon (1948) forms the basis of this direction of inquiry. Communication usually are preceded by a process of chit-chattering, brainstorming, signaling and messaging that can be analysed within a neural network, i.e. a biological phenomenon comprised of interconnected neurons that exchange messages with each other. Indeed, the notion of neuromodulators (Khalil, Godde and Karim 2019) for contributing to creativity could be quite similar to those provided by cultures, exposures and environment for inter-individual creativity.

Ideas work strangely through cells inside a brain. A deep learning researcher, Fjodor Van Veen (Asimov 2016), conveniently provided a Neural Network Chart describing the roles different cells in a human brain function. There are input and output cells, as well as noisy cells and memory cells. These cells communicate with one another in different *forms* and *layers*. Summarizing the work of a large number of neural research papers, the author created 5 broad categories of cell, 27 forms, and numerous types of layering depicted for the chart. The author pointed out that communications between cells have many variations, but "a layer alone never has connections and in general two adjacent layers are fully connected (every neuron form one layer to every neuron to another layer)." (Asimov 2017).

Unlike the internal operation of a brain, inter-individual communication in generating creativity may differ. We want to capture this creativity development in terms of a similar chart for memes evolutions. Individuals send out messages that the senders may not fully intend. Neither are the messages fully comprehended exactly as sent. This is a general observed norm in human communication. We abstract and extend Shannon's framework by describing an inter-individual communication chart as something similar to a neural system layer chart, but transforming the layer concept into a "stage" concept, denoting that there will be sequential time involved in meme evolution:

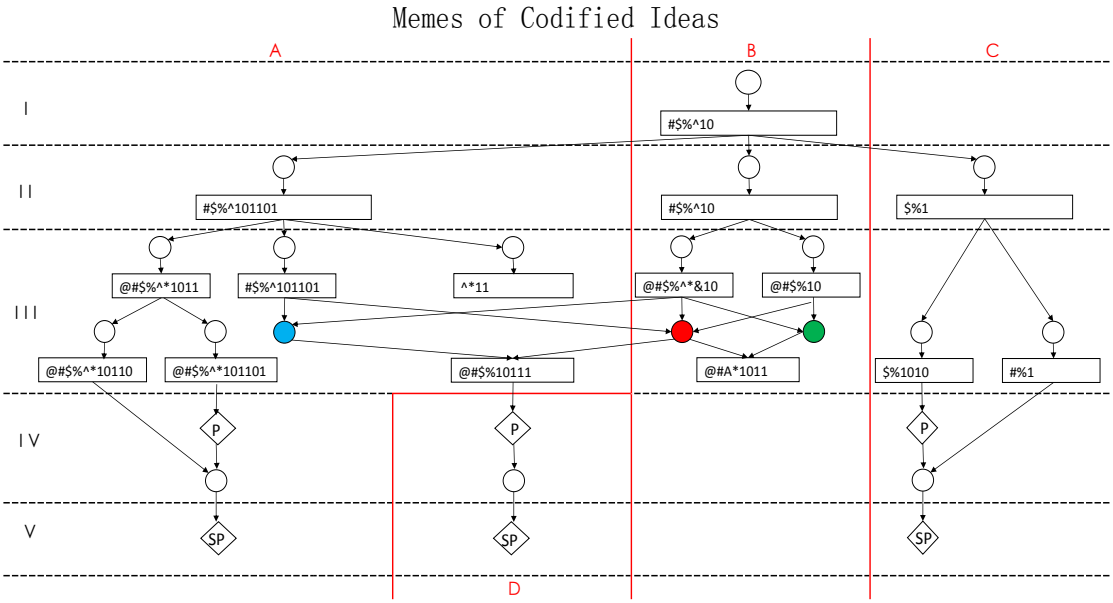

Figure 1. Sequential Time Stages of Meme Evolution

We choose several notations indicating players and actions involved in describing how ideas are developed in sequential stages. The notion of memes characterizes this process of information transformation in terms of players (entrepreneurs) denoted by **circles**, who have **ideas** (denoted by rectangular boxes of special symbols and digital details in 0 and 1). Approaches (paradigms) are denoted by **red-lined columns** labelled A, B, C, D. The schematic illustration in the figure gives examples of how inter-individual meme evolution is described in terms of layers, as information is being passed from one stage to another. The best way to understand the figure is to begin with the individual in Column B. He is assumed to be the individual who initiates an idea, even though generally speaking, there is no such thing, because all ideas are based on something else before the *first* idea. The individual under Column B in Stage II fully comprehends and duplicates information of the originator in layer I. Therefore, they form an approach categorically classified as B. Column A and C are different reactions to the original message of the individual in Stage I, and meme evolution of the ideas in each column promulgates and transforms in their own ways.

Stage I is the original of an idea. Stage II narrates how the idea is perceived and relayed to others. Stage II simplifies Shannon's communication system in collapsing transmitter with receiver in processing information reaching destination between individuals, emphasizing how messages are furthered relayed to individuals in Stage III. Stage III is where most collaborations take place. We expect various degree of filtering, consensus building as well as decision makings in this stage. Individual actions in this stage will formulate a suitable culture, exposure, and environment (CEE) for its preparedness for Stage IV. Like neural networks, information at this stage digs into the notion of convolution, interpolation, calculation, recurrence from short/long term memory, etc. (Asimov 2017). Choosing appropriate CEE will contribute to the success in Stage IV where physical embodiment of ideas will happen. Figure 1 shows that the four approaches come about in very different ways in the form of sequential time stages that each has to go through, with approach D appearing only after a while in Stage III. Approach D is what we could characterize as the outcome of interdisciplinary collaboration. It is the work of primarily two individuals, colored blue and pink. Those collaborations are different from that between individuals pink and green under column B. Identification of this outcome, of course, does not imply that other approaches for physical embodiment will not happen, as shown in column A and C.

An important aspect of Stage III is that there are ideas and meme evolutions that do not get anywhere. Ideas come and go. We can see that at Stage IV, the original idea (Approach B) is not being used any more. There are many ideas like that in real world meme evolution. They are used

only as steps arriving at the later stages. Many inventions and innovations in the history of civilization cannot identify its originator. Indeed, there are "usefulness to useless knowledge." (Flexner; Dijkgraaf. 1939, 2017). Useless knowledge can make a discussion of formulating ECC in Stage III to be more relevant, as investment in EEC is the only way that return to useless knowledge can be captured.

A very crucial decision in the information accumulation process is the embodiment of ideas into physical objects, **P**. This action will not come about until in Stage IV. One can think of what's going on in Stage I to III are all ideas transmitted from brain to brain, but there is no physical manifestation of "proofs" of the ideas. The proofs of an idea must go through a transcriptionist as we shall further explain in Section III of this paper. Stage IV is where some prototypes of embedding the ideas are created; it can be a simple gadget, a simple program, or a lab experiment that proves the "ideas" work, something that human with flesh and blood beyond a brain can feel. In other words, a *product* enters into the realm of reality that conventional tools of demand and supply used by economists will work to further coordinate its adoption and expansion.

Stage IV marks the beginning of a crucial transition from ideas to physical forms. The importance of this transition cannot be understated. This is often done in the form of a **prototype** or some physical objects that illustrate the ideas accumulated in the first three stages. Ideas without being turned into a Product, P, is rather useless as entities for firms to specialize in producing and for it be distributed via market. Ideas themselves are intrinsically not quantifiable unless it is embedded into quantifiable products. That, of course, does not mean it is nonfundable, as funding depends on prospects, not necessarily proofs. In discussing the concept, the best creative individuals can do is to conceptually codify them, which is what we are doing in Figure 1. Codified ideas are for showing how the process work, the meaning of which will be more carefully explained in the next section of this paper.

The meme development scheme outlined from Stage I to Stage III illustrates how an idea originates, then transmits, distributes in various stages, through numerous entrepreneurs, with modification, addition, deletion, and detailing before arriving at stage IV where certain physical embodiment and scale combination finally allows product marketing and packaging. Neoclassical economics as taught in most universities explains resource allocation under scarcity by stressing what comes after Stage IV. In terms of the schematic representation of Figure 1, the huge economic problem of resource allocation and institution choice has been untouched and poorly understood. The reason, of course, is that activities from Stage I to Stage III are intangible and unquantifiable, and therefore too slippery to be analyzed.

We can briefly describe what goes on beyond Stage IV, it is the experimental stage of prototypes. It takes human ingenuity to do that too, but thinking and experimental resources are much more focus on particular approach, rather than very broad-minded, interdisciplinary in nature. These individuals might work on their own (e.g. Approach D), or they can incorporate additional messages from others in their respective approach, but all working towards reinforcing the usefulness of their own approach, rather than discovering new approaches. This will lead to modified forms of prototype which the entrepreneurs could try sell or seek funding for implementation in Stage V.

The type of marketing and production in Stage V has been richly analyzed in the literature. Modified prototypes of product and process can take on two routes. The first emphasizes duplication and refining the production process of the prototype, relying more on what economists have labelled as division of labors and specialization, and more broadly projected, production emphasizing scale economies. The second emphasizes the combination of prototypes. By combining different prototypes, while allowing continuous refinement of the prototypes, there are new bundles of prototypes being created. The new bundles can create yet a new market, which competes with the prototypes and products of the original paradigms of A,B,C.D. Whether it is scale production or special bundling of prototypes, we represent that achievement in the last stage denoted by **SP**. To be sure, this stage involves experimentation also, with many aiming for customers (market) response. This is the stage where a new product (or bundles of products) can

enter the *real market test.* When ideas have taken their physical forms that can be manufactured, bought and sold in real time space dimension where contracts based on the physical forms are enforceable, the neoclassical tool of demand and supply kicks in.

Representing a sequential time stage process of ideas physical embodiment described in Figure 1 is intended to provide a framework to discuss pre-firm, pre-market arrangements. The literature is rich in analyzing what's happening in Stage V and after, but we do not seem to understand Stage I to IV very well, usually describing the stages in terms of a black box, reporting "after-the-fact" successful stories of collaboration. The thought process of individuals engaging in collaboration can take different routes and forms. One can complicate the narration further with subjective probabilities of evolution of outcomes. Embedding that consideration is not the essence of this narration.

Section II: Codified Ideas—An illustrative tool

Codified ideas as an illustrative tool are symbols that serve to be symbolic (Mason 1908), and in ways similar to what data scientists sometimes say about coding, they serve to show the model work rather than being used "in production". We make no distinction whether codified ideas are "codified knowledge" or "tacit knowledge" as discussed in the literature, e.g. (Cowen, Paul and Foray 2000). We explain knowledge transformation in terms of meme evolution of codified ideas.

Codified ideas in the boxes in Figure 1 are represented by symbols on the keyboard of a computer similar but more general than that used in ASCII specifications in that the keyboard used is specific to an individual. These symbols are expressed as outputs, messages, visuals communicated to another individual; but the input cells of the inner neural network of the individual receiving the messages may or may not see the same symbols communicated. This is because the outputs of an individual have to go through various "modulators" in order to feed into the input cells of the receiving individual, which after going through his own internal layers of neural communication within his brain, output as another "information" to other individuals. To enable a readable diagrammatic exposition, we assume the individual receiving messages do not communicate back to the same individual who sent him the messages. This is not a restrictive assumption that will handicap the exposition of the evolution of memes. The individual who "originates" the idea in Stage I can be one of those individuals receiving messages in Stage III, thus Stage I and III together can be a dialogue.

The symbols on the keyboard have various levels of wisdom built in for processing information. To enable a consistent interpretation of codified ideas in the information box, we assume special characters, e.g. @#%, denotes a particular software used for the personal computer that an individual is using externally or internally in the brain. The special characters are only a label for particular software which are brain processing algorithms used by an individual. The software used by an individual is a subjective choice selected by in the brain of the individual for cognitive and messaging purposes. It would be a language, a dialect, a methodology of thinking and calculating. The software used by one individual need not be the same software that another individual's computer is using; and therefore, the digital OUTPUT that is conveyed to the individuals in the next layer may not be the same as the digital information he receives from the layer preceding him. The concept of sematic distance can be brought into this discussion (Bao, et.al. 2011), but we shall not over-reach into that area in this preliminary inquiry of the problem.

The successive time stages for memes to develop implies that there is a history to the software used by interacting individuals. People usually approach a problem with prior knowledge (often tacit) from various sources, depending on the person's life experience. Their knowledges have some common platform to share. The commonality is denoted by the similarities as well as dissimilarities in the special characters used, e.g. @#% is identical for the first two characters with @#&, but they differ in terms of the third character. The approach of A in the diagram is denoted by a consistent adoption of a particular software, #$%^, even though it is being distorted/duplicated by three separate individuals in Stage III. One individual in Approach A, with the help of another

individual in Approach B creates the new approach of D. What distinguishes this collaboration from other interactions in that Stage is that the collaboration is interdisciplinary, i.e. across approaches (i.e. between individual circle blue and circle pink). The collaboration in this case leads to a product embodiment in Stage IV, which could be, say, the finishing up of a joint paper ready to be published.

Software are fed by digital information. We assume all digital information and their memes transformation and storage in a binary or digital code of 0 and 1. The series of 0 and 1 denoted in the boxes in Figure 1 refers to a series of "yes-no" questions asked in the context of particular software used. We assume the use of any software is preceded by a tree of "yes-no" questions. Individuals differ in terms of how many "yes-no" questions to ask before they input more serious digital information in describing an idea. The tree of "yes" and "no" can be simplified or shortened if a person answers "may be yes, and may be no" to a node of the tree. In that case, the question correspond to that node is deleted from the tree. A string of shorter digital 0 and 1 denotes a methodology of structuring the inquiry over fewer pre-conditioned questions. Sometimes physical embodiment of ideas can come about more effectively via asking simpler questions.

The complexity of idea can be represented by an architectural digital design where bits or computer words as a natural unit of data can be presented by bit lengths of 2^n, e.g. 2^3 represent binary word weight of 8, when 2^6 equals to a length of 64. The exponent nth of 2 is the string length of a set of digital information. All boxes in Figure 1 denoting ideas have detailed digital information that we will not specify in the diagram, suffice to note that they can be represented by combination "0s and 1s" in each box. As it is an integral part of a box, we shall not explicitly label it into Figure 1, so that the exposition of the diagram can be cleaner. The sequence and size of "0s and 1s" in the message depends on the number of characters on a computer keyboard needed in describing an idea. Thus, the exact digital content in each box varies immensely. For example, to communicate any of the 27 lower case letters of English language needs an approximate string length of 5 bits (00001, 00010, …,11111), while the 45,000 Chinese characters would require a string length of 16 (Freiberger 2015).

With information digitally imputed, all idea generation and transformation process can be described further with basic arithmetic computing operators or commands like addition, subtraction or multiplication. We cannot specify the string length in each box in Figure 1 because the special characters used across individuals denote the similarities (or the differences) in the software used by each individual separately. Depending on the software used, the degree of digital information (i.e. string length and keyboard characters) being fed into the software will differ. The types of codified idea therefore vary tremendously across disciplines. Thus, even within a discipline, individuals communicating could all aim at a common objective or a common mission of solving a problem, the digital inputs and outputs can be very different.

Section III: The Types of Interdisciplinary Collaborations

We will do some generalization and reasoning (Mason, 2018) in this section, starting with *a flash of genius* in Stage I. An entrepreneur of B communicated his idea to 3 persons in Stage II. The idea itself is described by a labeling of an implicit software used, followed by a series of digital symbols, #$%^10. Of course, the reaction to a Stage I individual's self-proclaimed flash of genius could be a complete dis-interest. I.e. the idea can be ignored, or worse still, considered as articulation from the month of a mad man. The 3 persons depicted in Figure 1 in Stage II receive the message from the originator and take some initiatives to relay. However, each individual in Stage II receives/relays the original idea with a different degree of understanding. The entrepreneur of idea A takes the original idea of B in stage I and adds something to it. The entrepreneur of idea C takes the original idea in stage I, subtracts something and adds something to do. The person in column B in Stage II adds nothing and subtracts nothing to the original idea of B in Stage I. He is a faithful disciple of the original idea. It is via through this relay authentication that an approach can be identified. Stage II thus serves as some type of characterization of receiving/relaying messages into 3 types.

(a) Enthusiast, Transcriptionist, Abstractionist

Stage II illustrates 3 types of information reaction to proposition in Stage I: Player in A column cultivates the approach of B in more details. He makes incremental digital contributions to the approach of Stage I. The person is an *enthusiast.* Player in B Column duplicates exactly the approach in the previous Stage. The person is a *transcriptionist.* Player in C column uses essentially a different software used by the individual in Stage I. The person is an *abstractionist.* There is little chance of collaboration between an enthusiast and an abstractionist, unless the abstractionist can find his followers in adopting his software for further enthusiastic pursuit. C's software shares only some of features of software used by B, $%. It captures a frequent reaction that people have coming out from a research seminar: "I know what the speaker is trying to say, I'd say it much simpler. My simpler method could be more useful." Most people are abstractionist when they come across general information.

Certainly, there can be a lengthy time lapse before any of the above three reactions kick in; and perhaps also, that the information can remain in the mind of a receiving individual for only a short while but only disappears completely later, with no legs for the original idea. In that case, the receiving individual with no memory of Stage I will not be listed in Stage II. There is no time duration built-in as a quantifiable parameter in any of the Stages. Also, we note that reactions of the three types are matter of degree. By varying the special characters and the digital inputs for the tree question of a software, it could reflect the personality and the subjective preference of why an individual react to an idea. Regardless of the degree of reaction, we can assert that the receiving individual listed for a schematic presentation as in Figure 1 must have at least one special character sharing with the originator in Stage I. Otherwise, there is not the slightest common platform for them to collaborate. The special characters could be a way to identify a concept called "epistemic community" as described in Hakanson (2010). We shall address to this in later paragraphs.

Another common reaction to a message is criticism. This is not ruled out under Figure 1 formulation. However, individuals in Figure 1 do not ask questions except on "yes-no" type after a software is chosen. They can criticize the originator in Stage I, but they do so by sending out their messages in subsequent stages, which might or might not be received by the originator in Stage I. As mentioned in earlier section, the individual in Stage I can reappear in subsequent Stage III to receive and send out messages. Therefore, there is no need to list the critics as a separate collaboration specie to study for in Stage II.

Finally, there are those who receive a message as pure personal consumption. They receive the message as similar to seeing a movie or the reading of a novel. They will not be listed in Stage II. This does not preclude that at one point in the future, something will pop up in their memories to help them formulate a flash of genius idea. This complication should not pose a challenge to the formulation of meme evolution in Figure 1, as it will simply imply that at that at a future date the person is starting his own new Stage I of a new chain of meme evolution. The messages he receives from historical consumption activities are part of the DNA of the software (special characters) in the software he will use then to communicate his messages to others.

(b) Integrative Information

There are many more players entering in Stage III. The accumulation of ideas (memes) takes on a form beyond just a subjective perception and interpretation by a person. It involves exchanges and modifications with different persons. Note that from stage I to III, ideas are going through metamorphosis **in the minds** of the entrepreneurs *only*. The digital information characterized by digital symbols and combined and modified, in the spirit of what can be called integrative information (Soh and Wang 2016; Lyng and Brun 2019)

The inter-individual collaborations are characterized in Stage III where communication expands with more memes evolved. This stage is akin to the complex neutral network inside a human brain where information can feed from many directions, with hidden layers omitted to simplify diagrammatic exposition. Approach A and B, for example, go through two layers of individual while the reality could be many more multiple layers before reaching Stage IV. The generation of ideas is also more diverse in that they can be across different approaches (paradigms), as between individual circle blue and circle pink. This is where interdisciplinary communication could be of importance, because they could provide the stimuli for generating a new approach which, in the diagram, is Approach D.

The simpler information communication pattern for Approach C is also displayed to provide a contrast. Meme evolution in that approach stays basically within the methodology of that approach, and does not entail interdisciplinary collaborations. It does not mean the software used in that approach is forever remain the same, because there will be improvement and extensions *within* the brains of the individuals in that column, even though individuals working under that approach are faithful to their approach.

Interdisciplinary collaboration can be definitionally described in terms of codified ideas as @#$%10111 in Stage III, which is an integration (as well simplification) of two approaches, A and B. We note that creative ideas sometimes come not by making it more detailed and more complex; it is by expanding, combining, and simplifying approaches that a physical embodiment in Stage IV can be achieved. Without arriving at Stage IV, all ideas are not protected, even with the most sophisticated IP laws, as no IP laws will protect basic ideas without a form. Nothing is implied in the diagram about how quick Stage III of an approach will be transformed to Stage IV. Indeed, for Approach B, it is not being transformed at all.

(c) Combinative Information

We are describing combinative information for Stage V, in terms of bundling and packaging of physical outputs. This is one of the two strategies of marketing physical goods in Stage IV. This is an assertion based on observation of different apps installed in a cell phone, the multi-functional chips installed in a driver-less car, and the many different ways that entrepreneurs compete in putting the proper bundle mix for final consumer. We assert that most interdisciplinary collaborations take place from Stage I to III. While there are integrative information generated also in Stage IV, they are not interdisciplinary in nature. This is an assumption embedded in the exposition of Figure 1. One might rightly question whether such assumption is over-restrictive. After all, there can be software (AI) recreated to package different components of a product for marketing. However, that AI invention is itself starting from some type of a Stage I flash of genius conjecture. By the time that conjecture has evolved to be implemented in packaging, it has already been physically embodied into the software (or device) that is doing the work of packaging. In that case, it is the original package with an AI enabled (definable, and scalable) component together that it can be considered as a new *combination* of information. It is not an integrative process.

Now suppose it is an entrepreneur that is doing some type of experimental packaging, e.g. a trial and error methodology, using tacit information and knowledge. Then, the sequential process is still at Stage IV. Most certainly, integrative information can happen at that stage. However, because the experiment is more likely to be market driven at that stage, we would not expect too drastic of a deviation from the approach that a physical embodied **P** has started. For example, during the early days in the gasoline driven automobile industry, electric cars already have been invented, but the industry at one point has chosen to focus on variations of gasoline driven cars only, not mixing it up with the electric car manufacturing technique.

We note that our discussion here is different from that in Hakanson (2010) in that a distinction between *integration* and *combination* of knowledge is categorized according to whether epistemic communities are creating new capabilities or exploiting existing capabilities (p. 1812). The author also believes the degree of codification is low for *integration/combination* (p. 1815). Again, we wish to stress that (a) the codification we have in this paper is for illustrative purpose

and does not have the same meaning of codification used in computer programming, (b) our exposition here emphasizes a pre-firm, pre-institution, and pre-epistemic community type of interdisciplinary collaborations.

That said, an example of a hypothetical family consisting of two children may serve to illustrate between the approach here and that articulated in Hakanson's research. Suppose a man-woman family gives birth to John and Jan. We can consider the children as *integration* of their parents. Alternatively, suppose both the man and the woman are divorcees, one brings a John and the other brings a Jan, this family is then a *combination*. In the context of this paper, the John and Jan in the first family cannot be easily identified as which part of them belong to the father and which part belong to the mother, their software and digital inputs are collaborative interactions of the father and the mother. The John and Jan in the second family, on the other hand, can be clearly identified as coming from which side of the family. The key being that John and Jan are being physically and separately embodied with the genes of each side of the parents before the family is formed. Hakanson's classification will give exactly the opposite result: the first family is a combination, the second is an integration. We leave this example for readers for further contemplation.

Conclusions

This paper describes how meme evolution via interdisciplinary collaborations can lead to new approach to knowledge creation in terms of codified ideas. The key to the success of all knowledge creation is the embodiment of ideas into physical objects, which in turn by scale production or by bundling, can yield benefits to the large population. Physical embodiment of interdisciplinary collaborations, like other embodiments, must go through the market test. Anything that has reached a market stage must be definable, quantifiable, unless it is service (labor hours) that one is selling. In that case, we will not be talking about product but factor market. Collaborative interaction there will be of an entirely different emphasis, more akin to the building up of human capital, and thus more has to do with training and education where physical embodiment will be intrinsically unmeasurable.

Our categorization of meme evolution, which is one among many possible forms like a Neutral Network Chart, assumes that information is processed through keyboard inputs, via different computer software installed on a computer (or in the minds of individuals), outputted into the monitor of the computer. They have colors and graphics, music, videos, and emotions to the extent that it can be captured by various emojis, but they may never mimic a face-to-face interaction in that the input cells of the receiving individual receive information from various senses. A meme evolution in the real world is unquestionably more complex. Describing information dissemination in terms of codified ideas is just a way to describe an interaction that is normally intractable and unquantifiable.

Acknowledgments

We thank Dai Ling for doing the Table, and traveling support from NYIT.

References

Arrow, Kenneth J. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity*, 609, Nat'l Bureau of Econ. Research ed. 1962.

The Asimov Institute. 2017. "Neural Network Zoo" 2016. "Neural Network Zoo Prequel: Cells and Layers."

Bao, J., Basu, P., Dean, M., Partridge, C., Swami, A., and Hendier, J. 2011. "Towards a theory of semantic communication." *Network Science Workshop Conference Paper*, IEEE Xplore.

Baruah J., Paulus P.B., 2019. "Collaborative Creativity and Innovation in Education." In: Mullen C. (eds) *Creativity Under Duress in Education? Creativity Theory and Action in Education*, vol 3. Springer, Cham.

Brown, J.S. and Duguid, P. 2001. "Knowledge and organization: A social-practice perspective." *Organization Science* 12:198-213.

Coase, R.H. 1937. "The Nature of the Firm." *Economica* 4(16): 386–405.

Coase, R.H. 1960. "The Problem of Social Cost." *Journal of Law and Economics* 3(1): 1–44.
Cowan, R.D., A. Paul and D. Foray. 2000. "The explicit economics of knowledge codification and tacitness." *Industrial and Corporate Change* 9: 211-253.
Demsetz, Harold. 1969. "Information and Efficiency: Another Viewpoint." *The Journal of Law & Economics* Vol. 12, No. 1, pp. 1-22.
Flexner, A. Dijkgraaf, R. 1939, 2017. *The Usefulness of Useless Knowledge*. Princeton University Press: New Jersey.
Freiberger, Marianne. 2015. "Information is bits." *+Plus Magazine, internet article*.
Hakenson, L. 2007. "Creating knowledge: the power and logic of articulation." *Industrial and Corporate Change* 16: 51-58.
Hakenson, L. 2010. "The firm as an epistemic community: the knowledge-based view revisited." *Industrial and Corporate Change* 19(6): 1801-1828.
Khalil, R., Godde B. and Karim, A. 2019. "The Link Between Creativity, Cognition, and Creative Drives and Underlying Neural Mechanisms." *Frontier in Neural Circuits* 22 March 20.
Kogut, B. and Zander U. 1992. "Knowledge of the firm, combinative capabilities, and the replication of technology." *Organization Science* 3: 384-397.
Kogut, B. and Zander U. 1996. "What firms do? Coordination, identity and learning." *Organization Science* 7: 502-518.
Lyng, H.B. and Brun, E.C. 2019. "Making your knowledge mine: the integration of external knowledge in cross-industry innovation." *International Journal of Innovation Management*
Mason, John. 1980. "When is a Symbol Symbolic?" *For the Learning of Mathematics* 1(2): 8-12
Paulus, P.B.; Baruah, Jonali; Kenworthy, J.B. 2018. "Enhancing Collaborative Ideation in Organizations." *Frontiers in Psychology 9: 2024*
Nelson, R.R. and Winter, S.G. 1985. *An Evolutionary Theory of Economic Change*. Harvard University Press.
Robson, Arthur, 2001. "The Biological Basis of Economic Behavior." *Journal of Economic Literature* Vol. XXXIX (March 2001), pp. 11–33
Romer, Paul. 1990. "Endogenous Technological Change." *Journal of Political Economy*.
Rosa, Jean-Jacques. The Second Twentieth Century: How the Information Revolution Shapes Business, States, and Nations. Hoover Institution Press: Stanford, California, 2006.
Shannon, C. E. 1948. "A mathematical theory of communication." *Bell System Technical Journal 27*: 379–423, 625–56.
Soh, Pek Hooi and Tao Wang. 2016. "A Typology of Innovation Ecosystems" (Competitive Advantage in Innovation Ecosystems) *Conference Presentation at the Sixth Beedie Innovation Conference,* CPA Innovation Center, Simon Fraser University, Sept. 29, 2016
Thayer A. L., Petruzzelli A., McClurg C. E. 2018. "Addressing the paradox of the team innovation process: a review and practical considerations." *Am. Psychol.* 73: 363–375.
Williamson, Oliver E. 1975. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Macmillan Publishers.