ENGINEERS AND SCIENTISTS: VALUE CREATORS IN THE SEVEN-PHASED MODEL OF TECHNOLOGICAL INNOVATION

(5500 words—23 pages)

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Accepted for publication in *Technology & Innovation*

Journal of the National Academy of Inventors, USA, December 2014

[The author gratefully acknowledges the generous gift of Mr. and Mrs. Tom Walter to the Thomas Walter Center for Technology Management, Auburn University in 2006. Their large gift and other gifts in Mr. Walter's honor by the Perot Foundation enabled the prolonged success of the Business-Engineering-Technology program on technology innovation at Auburn University. This study and other studies on technology innovation were made possible by the gifts to the Center, while the author served as the Director of the Center from 2005-2014, and as the Associate Director from 1992-2004]

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Abstract

The author has used the seven-phased model of technological innovation (Swamidass, 2015) to introduce to engineering students at the undergraduate, masters and doctoral levels, the *principle of upward cascading value of their ideas* once they are properly harnessed. This paper explains the simplified technological innovation journey as a seven-phased model to help more engineers and scientists to understand their value-creating role in the early phases of the journey. In addition, students also learn to protect this intellectual property with provisional patent applications to add value to their ideas and resulting products. The paper uses an illustration to show how the value created by engineers/scientists could cascade upwards. It comes as a revelation to engineering students that they can create value for themselves, for potential investors and for the economy with their engineering education. (133 words)

Key words:
Engineer-entrepreneur; scientist-entrepreneur; technological innovation; cascading value of ideas, seven-phased view of technological innovation; value creation by engineers and scientist; provisional patent; pro se patent application.

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Innovation: what is it?

The term "innovation" is used loosely today and there is no widespread agreement on what it means. While invention is something new, novel or unique, innovation is a new, unique or improved product or service that can generate revenue and sustainable profits for an established business or a new startup business. Technological innovation refers to engineering/science-intensive innovation; examples range from complex product lines such as smart phones, cars, aircrafts, FDA approved drugs, on the one end to simpler products such as small kitchen appliances, toys, hand tools, etc. that have imbedded technology.

Engineers/Scientists must think of themselves as value creators

University programs around the world do not enable engineers and scientists to think that they are commercial value creators. This is partly because their teachers and administrators don't think so. In this paper, technological innovation is viewed as a journey in seven phases (Swamidass, 2015), from idea to a mature, innovative business. This phased-view of technological innovation highlights the unique and vital role of engineers/scientists during the first two phases of the journey; while they play an important role in the later phases too, they play an almost irreplaceable role in the first two phases of technological innovation. Once engineers/scientists create value early in this journey, business professionals and investors add new business dimensions and more value to the creations of engineers. There is as if a *principle of cascading value* guiding an idea to a successful business.

The Principle of Cascading Value captured by a seven-phased model

The seven-phased model of Technological Innovation in Table 1/Figure 1 makes it easier to communicate with engineers/scientists. To seasoned business professionals and investors, the two-dimensional Seven Phases model in Figure 1/Table 1 may seem to be an oversimplification because of the model's artificial boundaries and strictly sequential progress over time. For the intended audience, who are engineers and scientists or students in these professions, without even a rudimentary knowledge of business practices, startup valuation, or investment, this model should serve as a primer, and open their eyes to their vital role in innovation during the first two phases.

One goal of the seven-phase view is to encourage hesitant engineer/scientist to kick-start the technological innovation journey with their ideas without being prematurely paralyzed into inaction by the unknown challenges of Phases 3-7 that tend to nag them before they even start. Walter Isaacson, known for his book on Steve Jobs of Apple Corp., said, "If you care about making good products, *eventually*, profits will follow [emphasis added]" (Lapinsky, 2014). So, the message to engineers/scientists: "First, care about making good products, rest will follow."

The Seven Phases of technological innovation: The journey

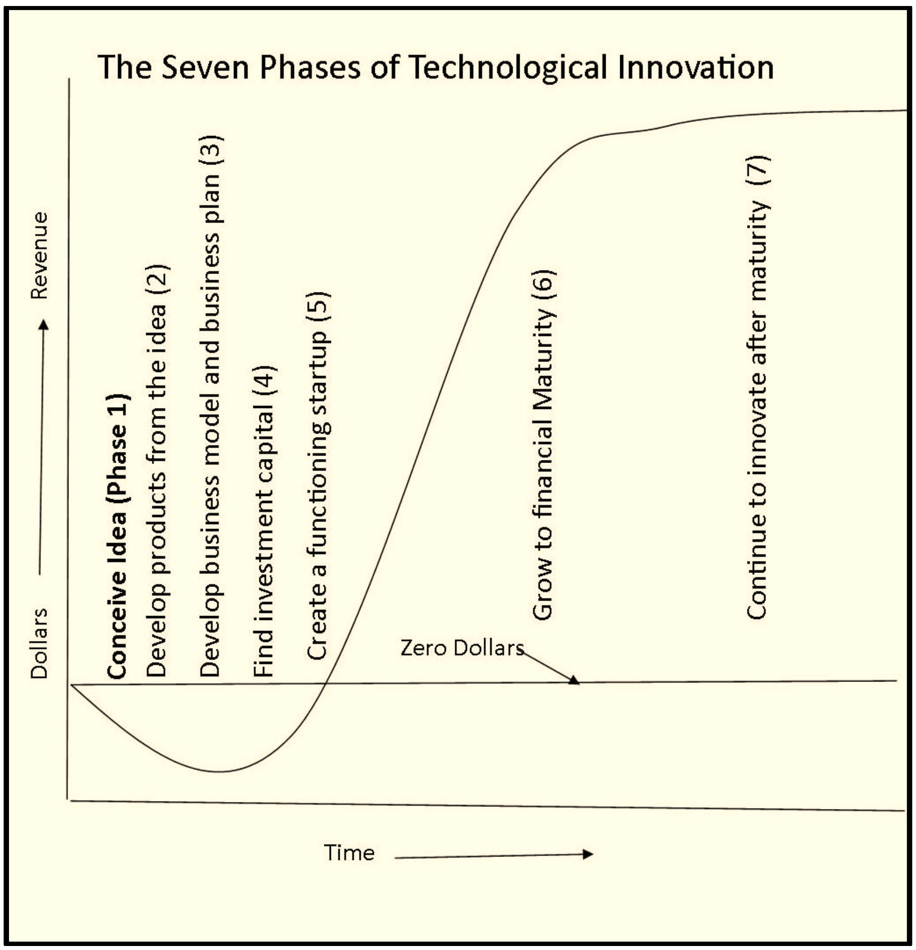
Cash-flow-based graphical representation of the seven phases

Figure 1 is a two-dimensional plot of **cash flow** during the Seven Phases of Technological Innovation starting from idea to last phase beyond stable, mature business. In this figure, cash flow ties all seven phases into a common journey making cash flow the common thread. The figure shows, approximately, where the individual phases occur over time. The **curve depicting cash flow in dollars from the start of the idea** begins at the line depicting zero dollars and dips down into the negative before becoming positive as the business is successful in generating revenue.

Table 1: Seven Simplified Phases of Technological innovation For Engineers and Scientists	
Phases 1-3: Pre-Startup Phases	**Invention Phase 1: Conceive an Idea** An idea to solve a problem or to grab an opportunity, refine the idea
	Invention Phase 2: Develop a Product (or service) from the Idea—Value creation Reduce the idea to a product or service for a target market, develop and improve it, protect the intellectual property
	Planning Phase 3: Business model and business plan development—Adding to the value Get help from mentors with entrepreneurship experience; form a management team, if possible. The business model, on paper, covers all aspects of the business to generate sales, revenue and profits. Business plan project cash flow for three to five years assuming the business model is functioning—investors look for business plans
Phases 4-7: Execution Phases—Financing the Startup and Beyond	**Execution Phase 4: Find Investment Capital—it is a function of the value created in Phases 2 and 3** Find capital (estimate, 1-24 months); form a management team if not done in Phase 3
	Execution Phase 5: Create a Functioning Startup Give shape to the startup (estimate, 3 to 30 months)
	Execution Phase 6: Grow to Financial Steady State or Maturity Financial steady state/maturity (24-100 months); the engineer/scientist may sell ownership and exit the business now with a handsome financial reward.
	Execution Phase 7: Continue to Innovate Beyond Maturity Past maturity, yet remaining innovative; Apple Corporation is a good example. In 2014, the company is more than 30-years old and is yet considered very innovative in Phase 7

In Figure 1, the cash flow in Phase 7 could be much higher than shown in the figure if the company remains technologically innovative in a manner similar to Apple Corporation, and others.

Figure 1



Caveat

First, Figure 1 represents a successful business from Phase 1 to Phase 7; only a small percentage of new startups are successful as depicted in Figure 1. In very simple terms, failure of a startup company is said to have occurred when the company fails to make strong positive cash flow wherin total revenue exceeds all costs by a good margin. Such a failure could be due to a number of reasons but the foremost being not enough customers to purchase the product or service at a price that would produce a positive cash flow.

The rate of failure among startup companies may range from 30% to 95% depending on the metric used. A study by Shikhar Ghosh, Harvard University, reports, "If failure means liquidating all assets, with investors losing all their money, an estimated 30% to 40% of high potential U.S. startups fail…If failure is defined as failing to see the projected return on investment…then more than 95% of startups fail…" (Gage, 2012) Additionally, the article notes, "Of all companies, about 60% of startups survive to age three and roughly 35% survive to age 10…."

Next, the reader is cautioned that, for the sake of simplification, there are lines drawn between two adjacent phases in the Table and figure but, in real life, these are blurred, and the activities of two adjacent phases may be iterative; for example, as the business model and business plan make progress during the Planning Phase 3, the information gathered during this phase may cause the innovator to go back to Phase 2 and improve the product by adding a new feature or by altering an existing function of the product. Therefore, while a sequential progress is implied in Table 1, technological innovation is never strictly one-directional from Phase 1 to Phase 7.

The reader is further cautioned that the duration of each phase varies substantially from one startup to another. Consider the largest Internet retailer, Amazon.Com; it took more than six years for the startup to make a small profit (1994-2001). However, many startup companies are profitable much sooner; complex products take longer to be profitable.

Pre-startup and Execution Phases

The seven phases fall into THREE distinct groups; Table 1 identifies the three groups of phases as:

1. Pre-Startup Invention Phases 1-2;
2. Pre-Startup Planning Phase 3; and
3. Execution Phases 4-7.

During Invention Phases 1 and 2, the engineer/scientist plays a lead role or even a lonely role. Further, during the Invention Phases, an idea is conceived and translated into a viable product/service for a specific market of targeted customers. If a viable marketable product or service does not emerge from Invention Phases 1 and 2, subsequent phases become irrelevant. As the journey moves to Planning Phase 3, the innovator may need the help of others with business and investment skillsets. A business model and ensuing business plan (for three to five years) is the product of the Planning Phase 3, which signifies temporary end to the Pre-Startup Phase. The business model and business plan will continue to evolve during the next phase(s).

Expect negative cash flow during pre-startup phase

According to the cash flow curve in Figure 1, a business produces positive cash flow after a functioning startup (Phase 5) begins to make sales. Until sales bring revenue, the cash flow is negative during the pre-startup activities; note, cash infusion from investors is not shown in the figure. The pre-startup negative cash flow could be very small for some businesses; certain software and web-based businesses are examples. Yahoo! search engine created by two Stanford University college students in the nineties was a grand success on a small personal budget—Yahoo! became an “overnight” success; venture capitalists came knocking to its door because of its cash-flow potential.

The importance of Invention Phases 1-2

It is impossible to over-emphasize the importance of Invention Phases 1 and 2 to an innovative engineer/scientist. A weak or shoddy work by scientists/engineers in these two phases could prove fatal to a startup business later. Business professionals, who may enter the journey in Phase 3 or later, sometimes, may be unable to correct the handicap of an ill-developed product during the Invention Phases 1 and 2. The author was once part of a startup business based on a university technology licensed to a private company. The company’s majority owners made some early technology choices that froze the future path of the company. When the technology proved to be a problem, it was impossible to change course because all the investment capital and bank loans amounting to several million dollars were invested in equipment that could not be salvaged; the business had to be terminated. Therefore, the science/technology innovator with a new idea must ensure that he/she does diligent “homework” during the Invention Phases 1 and 2 to increase the success of the startup business using their inventions.

Invention Phase I: Conceive a New Idea

Creative engineers/scientists, working as inventors in this Phase, would be well served if they develop the qualities that Isaacson (2011), a prominent biographer of Steve Jobs, saw in Mr. Jobs;

1. A controlled passion for perfection;
2. A keen eye for details;
3. The love of simplicity;
4. Thinking different; and
5. Thinking out of the box.

How do successful innovators find new ideas in this Phase that become successful products and businesses? The essential steps in this Phase are:

1. Germinate new ideas:
    a. Solve an unsolved problem;
    b. Meet an unmet need;
    c. Improve the solution to a major problem;
    d. Grab the opportunity to create new demand—example: before the time of cell phones, there were line phones only; cell phones created a new demand, created a new market and took away a significant market from line phones; and
    e. Improve a successful existing product already in the market to grab a part of the market or expand the current market; Nike's Air soles, introduced in the eighties, took away a significant portion of the market for athletic shoes from other shoe makers.
2. Define and clarify the idea in writing, and, after doing research, express the market opportunity clearly—it may require going back and forth between Steps 1 and 2; and

3. Define the target market—i.e., define who would buy the product or service, and how many customers may buy your product and why? If a target market is very small and cannot sustain a business, it may be better to revise the product, or drop it altogether. Experienced entrepreneurs say, "It is better to fail quickly and frequently." It is one way of saying, "Abandon bad ideas or products soon and move on to the next idea."

Ideas can be simple yet successful. Someone said, to create a billion-dollar company, "Create a $1 product that a billion people would buy;" this principle is within the reach of many inventors. One may appreciate the wisdom of this thought when you consider the hypothetical extreme opposite: "To create a billion dollar company, create a billion-dollar product that one person would buy." A billion-dollar product would be so complex, it would be a near impossible task to create one from scratch. Further, finding a customer for the one billion-dollar product would be near impossible.

The Infographic titled, "10 simple product ideas that made billions" (GrowAmerica, 2013), shows the power of simple ideas that became products with significant market demand and cash flow because large numbers of consumers valued these simple products. Examples featured by GrowAmerica include:

- Post-It notes invented by Art Fry in 1974 that generated $1 billion in revenue in 100 countries in 2012 (3M company product);
- Band-Aid invented in 1921 by Earle Dickson generated $3000 in sales first year; by 1961 Johnson and Johnson sold $30 million a year, and sales kept growing;
- Frisbee invented by Walter Frederick Morrison in 1937 was sold to Wham-O in 1955 and has sold over 300 million by 2012; and

- Velcro invented by George Mestral in 1941 is sold in 40 countries is a multimillion dollar business.

In Phase 1, if the reader wonders what it means to be creative, one may challenge himself/herself to answer some of the questions in the article, "15 most ridiculous college application questions" (Jacobs, 2013). Here is a sample of questions (there are no right answers):

1. "What are unimagined uses for mustard?" (University of Chicago);
2. "Using a piece of wire, a car window sticker, an egg carton, and any inexpensive hardware store item, create something that would solve a problem" (Johns Hopkins University); and
3. If you are reduced to live in a two-dimensional world, what would be your greatest problem? Opportunities? (Hamilton College).

Brainstorming for creative thinking

Brainstorming is an effective tool for creative outcomes during Invention Phase 1. It assumes there could be numerous potential solutions to a problem, while the goal of brainstorming is to find one "best" solution among numerous options. Keeny (1996) offers the following suggestions in the search for the "best" solution:

A. **Do not limit your solution alternatives during creative thinking**: Keeny distinguishes between *constrained* thinking versus *constraint-free* thinking. By constraining yourself to too few options, you may leave out many better options or even the best option. An example of *constrained* thinking he mentions is the national debate in the 1980s in the USA to reset the freeway speed limit higher than 55 mph after the 1973 oil crisis was history—the debate was focused on speed limit options of 55 mph and 65 mph only, which was further complicated by the desire to reduce annual fatalities caused by vehicle accidents—at 55 mph deaths were 10,000 fewer each year. Keeny calls this an example of "incredibly limited range of alternatives." He says, for reducing annual accident fatalities, one could have generated more alternatives, such as:

- Additional driving requirements for teenage drivers;
- Additional requirements for seniors with declining vision or skills; and
- Regulation and enforcement of child safety seats, etc.

B. Require individuals to generate alternatives and solution(s) before taking them to a group. Keeny fears one person in the group or one idea (an "anchor" idea) in the group may dominate the discussions while preventing good ideas from unprepared participants from emerging to the surface. Therefore, it is better for individuals to come prepared with their own list of solutions prepared individually, and then take the list to a group-brainstorming session. This would ensure that more good ideas will be on the table for the group to work with.

Protecting ideas during Invention Phase 1

When an engineer/scientist creates value during the Invention Phases 1 and 2, the idea or product may need the protection offered by a patent. If an innovator's idea were to become the source of an income stream, it is likely to be imitated or copied by competitors. The constitution of the US allows an inventor the opportunity to seek legal rights and protection to intellectual property under the US patenting system. However, the cost of patenting through attorneys (estimated as about $10,000 for a simple patent) may be a barrier to many young inventors. The US Patent and Trademark Office allows individuals to apply for patents without the need for patent attorneys (they are called "pro se" applicants"). Further, the United States Patent and Trademark Office (USPTO) offers assistance over the phone to independent inventors and pro se applicants; it also publishes the newsletter, *Inventor's Eye*, for the benefit of the independent inventor (USPTO).

Engineer/scientist can cut patenting costs during Invention Phase 1. Most inventors hesitate or even fail to move forward with their ideas and inventions fearing they cannot financially afford the cost of getting a patent to protect their inventions. They may not know that the TOTAL cost of securing a provisional patent (protection for one year) in the USA for an individual inventor considered a "micro-entity" (an individual with low income—most students would qualify) was about $80 in 2014. A non-provisional utility patent application and issue fee (IP protection for twenty years) for a relatively simple invention could be as low as $900 (for a micro entity in 2012-2013); the cost doubled to about $1800 (for a small entity in 2012-2013) for USPTO fees if the income of the individual did not qualify for "micro-entity" status.

Benefits of patent-search skills. Before applying for a patent, the engineer/scientist must do a patent search to see if it is worthwhile applying for the patent; the idea may not be patentable if it is already patented, if it is part of an expired patent, if it is part of a rejected patent application that is published, if it is not novel, if it is obvious (as defined by the USPTO), etc. The patent search may also yield powerful information to help an observant engineer/scientist to refine his or her product and make it more likely to be patented. The skills developed in conducting a formal patent search add value to engineers/scientists; skills they can market if they choose to pursue a career in patent law, or help them with future patent searches if they become serial inventors. At the end of a patent search, the conclusions could be (not exhaustive):

1. There are several similar patents, it is not worth pursuing this idea if IP protection is essential.
2. There are several similar patents. While a patent may be obtainable, it would be a weak patent. The decision to patent this idea is not black and white.
3. There are not many patents covering this subject. A strong patent could be obtained for IP protection.

USPTO interaction is friendlier than it used to be. The process of dealing with the USPTO for individual pro se inventor is steadily improving in the last few years, and Swamidass (2010) describes the assistance available to pro se applicants. Tangible help over the phone is accessible to all new and established inventors at the Inventors Assistance Center (IAC: http://www.uspto.gov/inventors/iac/index.jsp) of the USPTO.

Invention Phase 2: Reduce the idea to a product

During Invention Phase 2, the idea from Phase 1 is reduced to a tangible and viable product or service that has customer appeal and is targeted to specific market/customers. The following activities constitute product development for most products during Phase 2 (sometimes reiterated in Phases 3-6)--a manufactured product is assumed here—(some items in the list would be different for software or service innovations):

- **Spell out the goals for the product:** what does it do? How does it function?
- **Develop the functions and features of the product**: when first introduced, iPhone **function** referred to the smart phone that it is; **features** referred to a list of items that made it attractive to potential customers: the life of the internal battery, size of memory, camera, and so on;

- **Ascertain target customers and their needs**: without a customer, the best engineering/scientific product has no future in the innovation journey. Speak to a number of potential customers, or conduct a survey of potential customers to get customer input to identify and fine tune the functions and features desired by the potential customer; consult an experienced business professional, who could serve as a **mentor in this phase** for gathering customer input, or for designing, conducting and interpreting customer surveys;

Apply your engineering/science skills

- **Design and develop specifications for components and performance**: for example, for the iPhone, components and parts such as the case, battery, key pad, antenna, software operating system, etc. must be developed and specifications selected (example: battery specification would include battery dimensions, voltage, power, life of battery, time to charge, time to discharge, etc.);
- **Develop drawings, dimensions, specifications, and tolerances:** for each component and assembly to enable your manufacturing facilities to make the product, or to give to potential suppliers who would supply to your specifications;
- **Select materials for parts;** some materials are chosen for strength, some for appearance, some for electric conductivity, etc.;
- **Select assembly and parts manufacturing processes:** this could be approximate in the early stages of development only to be refined as the business takes shape;
- **Find and evaluate suppliers*:** a new startup cannot make every part or anything at all in the early days, therefore, it must seek suppliers for parts or full assemblies at a competitive price at a desired quality; for example, before iPhone was

launched, the decisions would have included, who would make and supply batteries, who would make the unique touchscreen glass*, etc.

***Suppliers can make or break a new product**. Corning Company had developed a proprietary glass called Gorilla glass in the 1960s. Without a market for the glass, the product was shelved and production discontinued. More than forty years later, Steve Jobs, head of Apple Corp., while looking for a touch-sensitive glass interface for iPhone, during product development, noticed the suitability of Gorilla glass for the new iPhone on the drawing board; he persuaded the head of Corning to restart production of Gorilla glass for iPhone decades after the product was shelved by Corning (Isaacson, 2011). Corning, as a supplier, was a key to translating one of the key features of the iPhone idea to the realized product.

The cost of prototype construction and testing. Depending on the product and the nature of business, a prototype may be produced and tested for performance as early as Phase 1 or Phase 2, if the cost of producing and testing is affordable. If the investment needed to build and test prototypes is significant, prototype building may be delayed until Phases 4 or 5 when investment comes in during the Execution Phases.

An illustration of the principle of upward cascading value of an idea

Once an engineer/scientist arrives at the end of Invention Phase 2, he or she has created value that can cascade upwards into something substantial. To elaborate this, let us use some hypothetical illustrative numbers within the realm of possibilities. If the value of the original idea at conception ranged from, say, \$100 to \$25,000, the value of this idea, when refined and reduced to a working prototype using extensive customer input, protected by a patent or pending patent could grow to, say, \$10,000 to \$250,000. This is pre-investment valuation in the estimation of potential investors looking for a technological innovation for investment. Investors use pre-investment valuation of the startup business or a product while negotiating full or partial ownership in the company in return for investment dollars. This is an important step in the value cascade.

How an idea continues to grow in value

After Invention Phase 2, the value of the startup reflects many things including the value of the original idea amplified by the product, the size of the potential target market, special access to the target market, a working prototype, computer simulations, and issued patents or patent applications to protect the IP. Progressive value-enhancement of an idea occurs during Invention Phases 1 and 2 that are under the control of the engineer/scientist without the need for assistance from outsiders such as business professionals, or investors.

Continuing with the above illustration, if the pre-investment valuation of the product or startup is say, $250,000 after Phase 2, it means that 20% ownership in the company would require a $50,000 (that is, 0.2 x 250,000) investment from investors. Thus, the value created by the engineer/scientist at the end of Phase 2 can be converted to investment dollars in exchange for partial ownership in the product or a company meant to commercialize the invention. It is not uncommon for an investor to buyout the entire startup for its full value of $250,000 from the inventor. This illustration is meant to show engineers/scientists how they can create significant value for themselves and for investors, who lack the technical skills to create new products themselves.

The role of business professionals in the value cascade

In due time, the addition of qualified, experienced business professionals to the management team after Phase 2 could further enhance the value of a potential or resulting startup business. Relevant background and experience of business professionals joining a startup may significantly enhance the chances of success of the business; it can induce investors to assign a higher pre-investment value to the startup. In one case, the valuation of a new startup was significantly elevated by a group of angel investors[1] because one of the executives in the proposed software business had 20 years of management and product development experience at Microsoft—very relevant experience for the proposed product/business. If we continue with the above example of a startup valued at $250,000 at the end of Phase 2, with the addition of experienced business professionals, the startup may be valued at $500,000; an investor must then invest $100,000 in return for 20% ownership in the startup.

The value of business models and business plans

With the addition of a validated business model (an agglomeration of business decisions to ensure sales, cash flow and profits), and cash flow estimation for three to five years using a business plan developed during Planning Phase 3, the valuation of the startup could increase or multiply. This is because the business plan could reveal to the potential investor additional information about the revenue streams, expected costs, proposed activities of the business, cash flow, profits and return on investment; the potential investor gets to judge if the assumptions behind these details of the business plan are justified. The business plan does detailed leg work for the potential investor, makes the proposed business more transparent to the risk-taking investor, and also gives the potential investor the opportunity to question and challenge some of

[1] Angel investors invest in early stage companies, more risk tolerant, wealthy, and expect very high returns from a few while tolerating the failure of others.

the assumptions. It also enables the investor to participate meaningfully with the company to improve the business plan prior to making an investment.

If we continue with the above example, the pre-investment valuation may reach $750,000 once a strong and valid business model and business plan are accessible to investors. If so, an investor must invest $150,000 in return for 20% ownership in the startup company. This illustration shows the engineer/scientist what they could do to grow or multiply the value of their original idea, and how far they can take it. In this hypothetical illustration, the inventor could get an infusion of $150,000 from an investor for only 20% share of the company; the company also gains by the knowhow and network of people and businesses that come with the investor.

Without the engineer or scientist moving his/her idea to the end of Phase 2, the idea could have been discarded prematurely before investors could invest. The purpose of this hypothetical illustration is to say emphatically to engineers and scientists that their ideas can acquire considerable value to themselves and to investors if they can move their ideas to Phase 2; the phased view of technological innovation enables us to communicate this very powerfully.

CONCLUDING NOTE

The course titled, “Engineer-Entrepreneur,” offered as an elective by the author had about 30 engineering students in two different semesters at the undergraduate, masters, and doctoral levels at Auburn University; a similar course was offered by the author for more than ten years as an elective to both business and engineering undergraduate students working in joint teams. At the request of a professor of biological sciences, who teaches microbiology at Auburn University, the next offering of the course will admit students from sciences also, and the course will be titled, “Engineer/Scientist-Entrepreneur.”

Some non-traditional yardsticks are used to gauge the effectiveness of this course. First, the author noticed that engineering students are motivated to stay in this non-traditional elective course by the intriguing thought that they can use their engineering college education for creating value through inventions, product development and IP protection.

Second, over a seven month period in 2014, nine individual students or team members have applied for provisional patents as pro se applicants to protect their IP with the intention of monetizing their ideas with some mentoring by the author outside the class. While patent application to the USPTO was not a course requirement, many students promptly applied for provisional patents to protect their IP using their new-found knowledge of preparing a provisional patent application. Outside of the class, they also learned the process of filing provisional patent applications electronically with the USPTO—the whole process took about four weeks after the course was completed. The voluntary effort they put into the filing provisional patents for their invention is a better yardstick than any we can device. The students, who did not file a patent promptly, said they do not yet have an idea worth devoting their time to IP protection, however, they said they are confident they can apply for one, when needed. At the end of the course, students felt empowered to turn their ideas into products and protect the resulting IP; they have learned the basic tools to be serial inventors and value creators for themselves, for potential investors, and for the economy.

Third, some engineering students in the class are considering the lucrative patent law profession after graduation. One former student, who applied for multiple patents before graduation, joined a patent law firm as an engineer. In his letter to the author in the summer of 2014, he said: “Just wanted to let you know that my first issued patent recently published…Thanks again for all your help along the way! “ In an another email he said, “Also, one of your pervious students,…, is doing some part-time work for Grant and I. She's helping us draft a few patent applications. So far, her work has been excellent."

While teaching the course, the author had three issued patents as of 2014 and had several pending patents; students noted that the author's use of his own patents in class discussion, his ideas that led to issued patents, and his experience with the patent application process as a pro se applicant, made them believe they could apply for provisional patents without using the services of patent attorneys, or at least until they could afford such attorneys later in life. The course is waking up the serial inventor inside our future engineers. As a teacher, it was rewarding to hear engineering students generating and evaluating a boundless range of ideas.

REFERENCES

Gage, Debra (2012) "The venture capital secret: 3 out of 4 startups fail," *The Wall Street Journal,"* Sept. 19, 2012.

GrowAmerica, "10 simple product ideas that made billions," An Infographic, http://www.pixelroaddesigns.com/portfolio/10-simple-product-ideas-that-made-billions-infographic/ (accessed June 17, 2014).

Isaacson, Walter (2011) *Steve Jobs,* Simon & Schuster, New York, NY.

Jacobs, Peter (2013) "15 most ridiculous college application questions," Business Insider, July 19. http://finance.yahoo.com/news/-the-15-most-ridiculous-college-application-questions-160531465.html?page=all (accessed July 2013).

Keeney, Ralph L (1996) *Value-Focused Thinking: A Path to Creative Decision making*, Harvard University Press, Cambridge, MA.

Lapowsky, Issie (2014) "Walter Isaacson: 5 traits of the true geniuses," *INC Magazine*, http://www.inc.com/issie-lapowsky/walter-isaacson-5-traits-true-geniuses.html 3/3/2014 (accessed June 16, 2014).

Swamidass, Paul (2010) "Reforming the USPTO to comply with MPEP §707.07(j) to give a fair shake to pro se inventor-applicants," *John Marshall Review of Intellectual Property Law, Vol 9 (4), pp. 880-911.*

Swamidass, Paul (2015). *Be an Engineer-Entrepreneur: 10-Week Blueprint for Engineers and Scientists,* forthcoming book.

USPTO, Inventor's Eye Newsletter, http://www.uspto.gov/inventors/independent/eye/201404/inventorseye_new_orgs.jsp