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Technological Innovation and Intellectual Entrepreneurship: Challenges for Institutions of Higher Learning in Developing Countries

Abstract:

Most developing countries in the Asian region have yet to adequately recognize the fundamental relationship between higher education and wealth creation. It seems that the adherence to a traditional mindset regarding the "economic factors of production" and the very restrictive view of technology as "some form of machinery only" are two major impediments to a clearer appreciation of the pivotal role of the institutions of higher learning. In this paper, I begin with the total spectrum of resources available to all organizations engaged in the economic value addition function, and the crucial role played by the four dynamically interacting components of technology — the intelligence based created resources — in making their organizations both efficient and effective in an increasingly complex and competitive world. Within this framework, I have incorporated two recently learned lessons. Firstly, it is now universally accepted that "technological innovation" is the key for national development in the globalized environment. Secondly, now it is also apparent that new entrepreneurs are attracted by the potential of those technological innovations that bring together the emerging intellectual properties generated by the institutions of higher learning and the perceived demands for goods and services by global customers. By focusing on the triangular linkages of the national innovation systems, an attempt is then made in this presentation to explain the importance of "intellectual entrepreneurship" and the desired role of the institutions of higher learning in developing countries.

1. Introduction

Not too long ago we considered land, labor and capital as the only factors of production, and thought that natural resources were the primary sources for economic value addition. But then Japan, South Korea, Singapore, Hong Kong, Taiwan and many more have shown that there are other resources that are even more important than natural resources. In the annual report of 1999, the World Bank officially recognized: "Poor countries not only have less capital, but also have less knowledge" [End Note 1 and Ref. 12]. Much before that, at the United Nation's Asian and Pacific Center for Transfer of Technology, I tried to convince the policy-makers in developing countries that the real gap between the developed and not-developed nations is "not money, but technology" [Ref. 2]. Now, proven by the success of the industrialized nations, technology has indeed emerged as the ultimate resource for wealth creation. It is a fact that only societies who have "technologies" (in various resource embodiment forms, with synchronized capabilities and competencies) could achieve economic prosperity [Ref. 4]. And if we learn to manage "it" well, there appears to be no limit to technology-enabled development of the world. I have put quotation marks to indicate that we still lack clear understanding and worldwide standardization of the term technology.

Surfing on the Internet, one finds that the leaders of most international organizations are making frequent speeches all over the world, saying: "Technological innovation is a crucial factor to economic growth and development." It is also very common today to read such statements made by most of the leaders of the industrialized world: "Technological innovation lies at the heart of a nation's ability to sustain a healthy rate of economic growth and productivity, and to maintain competitiveness in the increasingly knowledge-intensive global economy." Their lectures include: "Knowledge has become the engine for wealth creation … Knowledge contributes to development through the creation of intellectual capital … Knowledge and knowledge-workers are the source of wealth in post-industrial societies" [End Notes 2 and 3]. Clearly, there is a growing perception that accumulation, generation and sharing of knowledge constitute a fundamental driving force behind present day economic wealth creation. In the developed country economies, this fact is reflected in many observable trends toward increasing investment by both the private and the public sectors in knowledge management [Ref. 7]. Employment in the knowledge sector, in which educational and professional qualification that contribute to technological innovations are specifically required, has been growing steadily [End Note 4]. However, due to lack of consensus about various embodiment forms of technology, we often cite that the new factors of production that are becoming more and more important for economic growth and societal wealth creation are "intangible" or non-physical.

The purpose of this presentation is to venture inside the technology "black box" and to explain how the institutions of higher learning in developing countries could focus on intellectual wealth creation. My starting point is the assertion that continuous technological innovation is our second nature. It is obvious to any historian that human interests propel technological innovations in a perpetual motion. This is because human beings are generally creative in doing things, they are inquisitive about unknowns, and they are also persistent in pushing apparent natural limits. Human beings in every place and time naturally innovate and apply/utilize technologies to do all kinds of things. Applications of technological innovations help satisfy human needs by enabling us to do – more things, better things, newer things, and things better and faster than ever before. Besides being creative, human beings also like competition, seek excellence, and enjoy superior status. All achievements, derived through technological innovations in the past through the present, raise our overall aspirations. Hence, new opportunities and threats provide powerful self-motivations for further technological innovations. Therefore, it seems there is little doubt that technological innovation is in perpetual motion. Moreover, we see that these individual human characteristics also manifest in our collective context of organized purposive work environment.

2. Technological Resource Innovations Are Essential for All Organized Activities

All organizations and projects are a collection of people united for desired purposes, and as such, they rely on a combination of the following four types of generic resources: (1) *nature-based derived resources* (e.g., matter, energy, land, water, space, etc.); (2) *intelligence-based created resources (*which are: tools, skills, facts, and methods); (3) *goodwill-based bestowal resources* (e.g., connections, reputation, credibility, glamour, etc.); and (4) *convenience-based surrogate resources* (including: money, credit rating, insurance, etc.). Next, let us observe two technology-related issues in organized endeavors. First, every organization (private or public) performs some kind of transformation of available "inputs" to desirable "outputs" (various goods and/or services). ***Technology***, which is the *human-made intelligence-based created resource*, ***is the mechanism*** that performs or enables the transformation for the production of goods (consumption, intermediate, capital, and intellectual type) and services. Second, over the years, all organizations have come to accept technology ***as the means*** for managing productivity-driven competitive advancement in an open economic environment. Throughout the world, our relentless effort toward productivity gain has resulted in continuous technology-resources sophistication for efficient process management and effective value networking. Thus, technological-resource innovations (for better mechanisms, and for better means) are indispensable concerns of all organized endeavors [Ref. 4]. Figure 1 shows schematically the role of technology and other resources in all organizations.

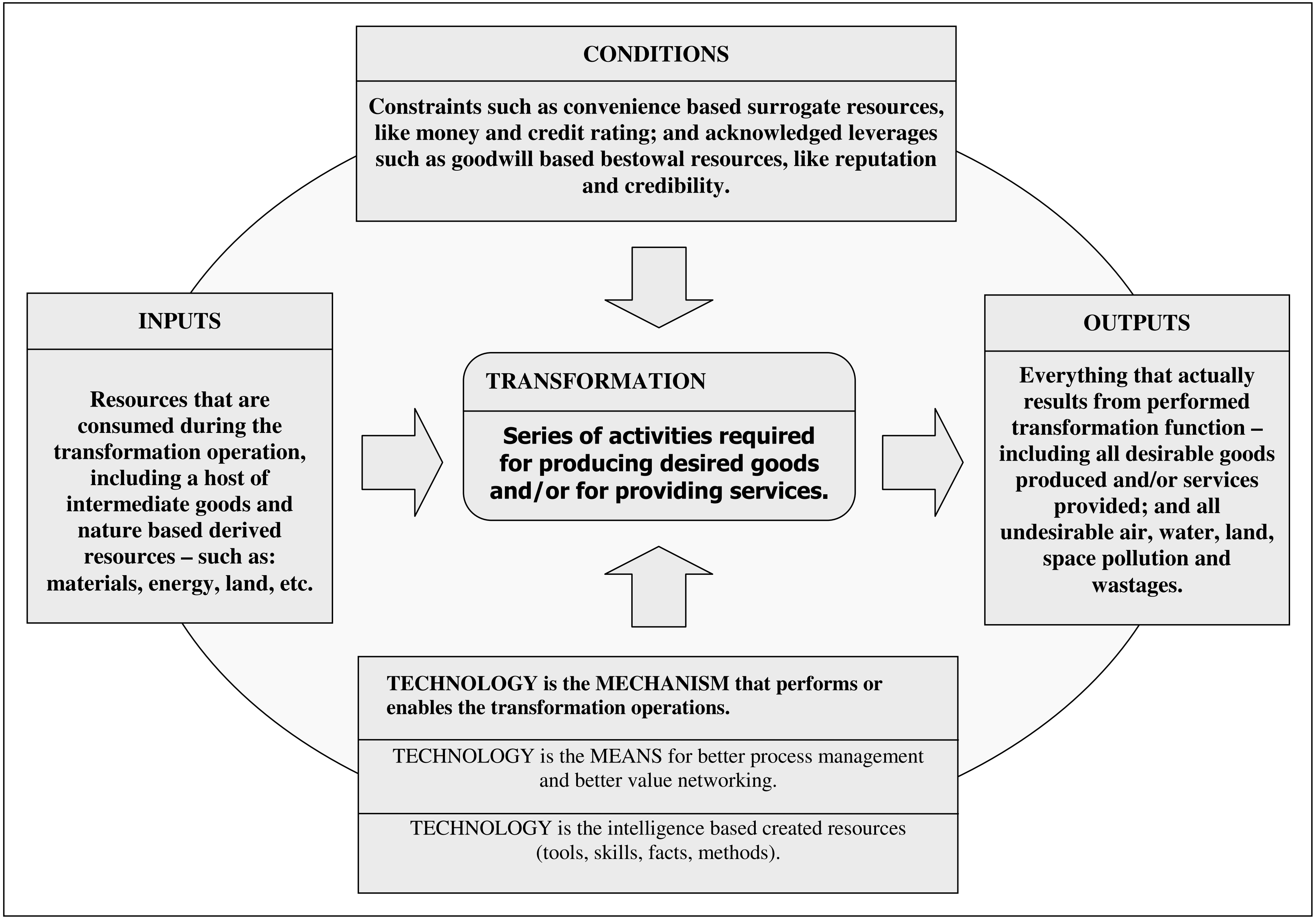

Fig.1: Role of Technology and Other Resources in Organized Value Addition Endeavors

Before we move on, it is useful to remember that technological resource innovations are essential, but not necessarily sufficient for better performance. We also need, concurrently, both "technological capability" and "technological competency" innovations. Unfortunately, in the literature, one will find the distinction between capability and competency very blurred. But then why should both be preserved if they can be used interchangeably? In my view they are different. Technological capabilities can be acquired, in an organizational context, through collective (team) learning by – doing, failing, changing, and practicing within current technological constraints. This kind of experience-based learning helps goods producers and/or service providers increase their efficiency (which is doing things right) by reducing cost of rework and waste, and by using better (alternative) inputs**.** Capability is acquired through deliberate learning by reactive and preventive approaches to problem solving through: identifying problems; prioritizing problems; treating problems; and preventing problems. On the other hand, technology competencies can be elevated, in an organizational context, through planned interaction with stakeholders by listening, observing, imitating, and emulating best practices and shifting technological constraints [End Note 6]. This kind of expertise-based intelligence helps customers' or clients' value addition effectiveness (which is doing the right things) through: increased quality and improved attributes of outputs; and by meeting special requirements. Competency is acquired through deliberate intelligence gathering for proactive and productive solution-seeking using information technology and networking in: defining requirements; finding solutions; improving solutions; and promoting credibility. In short, I would like to say that capability is based on "collective experience with explicit knowledge" and internal organizational-specific acquired efficiencies; and, competency is based on "collective expertise of tacit knowledge" and external-situation-specific desired effectiveness. This distinction may be useful to understand the role of higher education in promoting intellectual capital.

Now, having eluded the purposive and intimate relationships between organizations and technological innovations for survival and progress in the competitive world, I now direct your attention to a simple description of technological resources (I call them components) that we have become so accustomed to, and hence have often overlooked. In essence, the decomposition takes us inside the so called "technology black box," and makes it easier for us to critically assess the complicated issues related to technological innovation and wealth creation.

3. Distinctive Dimensions of Technological Resources Innovation

Different individuals, based on their professions and experiences, tend to perceive the term "technology" quite differently. In a general academic sense, technology has been broadly defined as the application of scientific knowledge that enables the manipulation of human surroundings for the practical purpose of meeting ever-changing human aspirations. Coupling this with our earlier belief regarding the crucial role of natural resources, one can argue that, technology usually rests on a natural phenomenon and on some schematic logic for manipulating that phenomenon to fulfill a certain human purpose. This kind of broad definition may be acceptable to many, but I believe practitioners seek something more specific and also something that can be measured to manage it well. The following is what I have learned about the embodiment forms of technology through numerous interactions with practitioners over a long period of time [Ref. 9 and 10].

In the context of an organization (either public or private), technologies include all kinds of *human-made helpmates*. All of those human-made helpmates are essentially *the intelligence-based created-resources*, such as, tools, skills, facts and methods that are used as the *mechanisms* for different transformation activities and also as the *means* for managing the various organizational functions most productively (efficiently and effectively). In a simple and intuitive way, it can be observed that, for converting the procurable inputs to the desirable outputs, and for all types of management processes activities, every organization uses a unique combination of quadruple technology components. These components are individually found to manifest in the following distinctive embodiment forms (designated as the basic components of technology):

- Tools → Object-embodied physical-operational technologies, like artifacts and machines. This component of technology is the necessary core for every management-process and production-related task and can be designated as "technoware". Technoware is the physical device of technical performance that amplifies human capacity (both muscular and brain related) for producing different kinds of goods and/or services through various types of transformations (for conversions of available inputs to desirable outputs). Technoware is also used as an enhanced means for managing processes (for efficiency and effectiveness): to provide information systems; to enable value networks; and for other activities.
- Skills→ Person-embodied art-of-doing-type technologies, like ingenuity, craftsmanship, and talent. This component of technology is essential for accomplishing

any tool-assisted task and can be designated as "humanware". Humanware is what people really do with their technoware. It includes tacit knowledge (which is knowledge that is not documented, or recorded, or codified) and is also used for both transformation activities and managing various processes. Without relevant humanware, any technoware is simply non-functional or useless for actual performance of the transformation or for management.

- Facts → Record-embodied know-what-why-how-type technologies, like systematized concepts and professional specifications. This component of technology is the primary source of human creativity related to a tool-based task of transforming and managing, and can be designated as "inforware". Inforware is the codified (which is explicit) knowledge and information base underpinning a technological mechanism for a transformation operation or a means for managing a process. Inforware enables quicker skill development and also gives savings in terms of time and resources utilized for any activity.
- Methods → Institution-embodied work-procedural technologies, like recipes, operational steps and techniques. This component of technology essentially refers to the process of organized work that makes the task-tool relationship useful and rewarding and can be designated as "orgaware". Orgaware is like a problem-solving routine related to an activity. Orgaware includes systematized knowledge of the logic and method for integration and coordination of activities and resources for achieving desired goals of an organization.

All four components of technology, described above as embodiment forms of intelligence based created resources, interact dynamically and are required simultaneously by an organization for successful performance of any desirable goal. For example, we know that in the context of any particular transformation or management task performed, an organization can choose a technoware from those available with a certain degree of sophistication, such as: manual tools, powered tools, automated tools and programmable tools. However, since a more sophisticated technoware often comes with certain built-in humanware, it will need a different level of skills-set, and may also require more sophisticated inforware and orgaware for cost effectiveness. Very often, tacit skills (humanware), codified knowledge (inforware) and specified process (orgaware) become much more critical with sophisticated tools (technoware). Thus, the actual selection of the dynamically interacting quadruple technology components for a particular transformation or management function is indeed very complex. Moreover, there are certain inherent tradeoff characteristics regarding the four technology components that should not be overlooked. For instance, any labor-intensive technoware usually requires higher-level humanware and more labor-discipline. The best inforware is well written, illustrated and complete so that the codified knowledge can be used by an organization for changes leading to better performance. Also note that, tacit knowledge is merely implicit wisdom or humanware, and as such is not yet inforware. Likewise, unimplemented or non-utilized techniques, such as the project and process "information management systems" and "capability maturity models" are merely inforware, not orgaware. Besides, all orgaware encoded in techniques have their own underlying axioms, assumptions and limiting conditions (inforware).

It should also be noted that different combinations of specific technology-components with certain minimum degrees of sophistication are needed for different types of transformation and different process management activities. Moreover, the relative importance of the four technology components necessary for different transformation functions (all kinds of converting operations) and management processes (all kinds of decision making activities) also depends on the specific activities involved. However, irrespective of the minimum required degree of sophistication of technoware, humanware, inforware and orgaware for a particular transformation or a particular management activity, real world examples show that, if properly done, innovation to a higher-level of sophistication can give a competitive edge. Also, whatever is done by any organization, at the industry or sector level, each of the quadruple technology components necessary for related management functions and related transformations are being continuously made more and more sophisticated due to our keen desire to compete, excel and lead through productivity gain. These changes are generally incremental in nature, and are seen to be punctuated by occasional radical changes. Typically, the latest technoware may be observed as – state-of-the-art, fully tested and applicable, well protected through patents, and relevant to the market demand. Characteristics of the latest orgaware may include – built-in risk management process, consideration of government policies, and the opportunity for creativity. However, it is apparent in many emergent sectors that orgaware innovation has not kept up with technoware innovations. Without going into much more detail, I conclude this section by stating that technology component innovation can be considered as the task of introducing higher degrees of sophistication, which can be achieved either through external sourcing (known as technology transfer – or buying) or through internal efforts (known as technology development – or making) – both of which involves many complementary research and development (R&D) activities. In fact, R&D can be labeled as the "factory" for technological innovation, which exists in three domains, and includes a diverse array of activities [Ref. 1 and 3].

4. Domains of R&D and Triangular Linkages as Determinants for Technological Innovation

Generally, research and development (R&D) efforts for technological innovation can be seen as a spectrum starting at the conceptual end (the domain of university or knowledge) and ending at the commercial end (the domain of industry or market). These are commonly classified as – (1) basic and fundamental R&D; (2) applied and empirical R&D; (3) generic and platform R&D; and (4) niche and differential R&D. People also consider these four types of R&D forming a bridge between "new ideas" (the supply push end) and "new needs" (the demand pull end). In fact, empirical studies give plenty of evidence that the push-pull forces conjunctively contribute to the success of R&D efforts. We also know that the academic, production and services sectors of the national economies undertake different portions of the above-mentioned R&D efforts. Collectively they form the innovation triangle, as shown schematically in Figure-2, which is the core of the national innovation system. Each element of the innovation triangle performs many important functions and has a distinctive focus. For example, the R&D units in the academic sector deal with ideas and concepts; the R&D units in the services sector (independent public or private institutions) are concerned with devices and their designs; and the R&D units in the production sector are primarily concerned with production problems and artifact feature related issues. The national innovation system also includes support services provided by organizations engaged in – information and forecasting; design engineering and consultancy; standardization, testing and certification; public venture capital and intellectual property registration; etc.

Now, turning our attention to the technology components, it can be seen in Figure-2 that even though technoware, humanware, inforware and orgaware are all made more sophisticated by the interaction of the innovation triangle, each of the technology components has some unique relationship with specific R&D efforts. Generally, for example, R&D in the academic and services sectors tend to produce orgaware; R&D in the academic and production sectors tend to produce humanware; R&D in the services and production sectors tend to produce technoware; and all types of R&D efforts produce inforware either directly or as by-product. Since all four technology components (technoware, humanware, inforware and orgaware) are required simultaneously by all organizations (for transformation and management functions), the most important requirement for a thriving innovation systems is the existence of adequate networking among the triangular R&D units and the support services in the country. Moreover, successful university, industry and R&D interactions are not merely a technical matter. It involves non-technical factors such as: differing interests and priorities; unlike organizational and cognitive cultures; and traditions. The system must develop ways of generating new scientific and technological knowledge and converting it into useful, socially acceptable, as well as environmentally desirable new products and processes. Social, cultural and economic convergence is crucial for the success of the innovation efforts.

Before moving to the next section, it may be useful to note some of the critical concerns with the national innovation system effectiveness. Studies in the industrialized countries show that technological system innovation is increasingly concerned with complex products and processes. These complex systems are innovated by self-organized networks among the triangular R&D elements of the national innovation system. Three intertwined factors for successfully linking the innovation triangle are: (1) complementary assets and competence; (2) exchange of explicit and tacit knowledge; and (3) ability in scholarship of integration. In developed countries, effective networks are being established by linking organizations that create, acquire, and integrate the diverse knowledge and skills required to innovate complex technological systems. Observing tacit knowledge and integrating it with codified knowledge is a particular strength of many people in these networks. In most developing countries, the linkages are either missing or very weak, and the institutions lack minimum "critical mass" required for significant contribution to technological innovation. One reason for not doing much about these weaknesses in the innovation triangle is perhaps our inadequate appreciation for intellectual property and intellectual entrepreneurship.

5. Intellectual Properties and Intellectual Entrepreneurship

In an organizational context, we can consider innovation as knowledge applied to tasks that are new and different, and for this presentation we are focusing on new knowledge that manifests in the four technology components – tools (technoware), skills (humanware), facts (inforware) and methods (orgaware) – for better transformation and better management. Since all components are human-made created resources, intellectual property rights can protect them for exclusive use to recover the cost of their creation and to encourage creativity. In other words they are "intellectual property." The term intellectual property has been coined and relates to intangible property such as patents, trademarks, copyrights, and trade secrets. It is the output of intellectual activities of either authors or inventors. However, intellectual property rights cannot protect tacit knowledge or even explicit knowledge if they are not properly registered. These fall under the category known as the trade secrets. These are either tacit-knowledge (which are extremely difficult or impossible to codify) or deliberately non-disclosed explicit knowledge (one reasons being the potential for easy learning), which are protected only by employment contract clause of non-disclosure. Figure-2 indicates the relationship between intellectual property rights and components of technology. A brief synopsis on patents, copyrights and trademarks is given in the following paragraph.

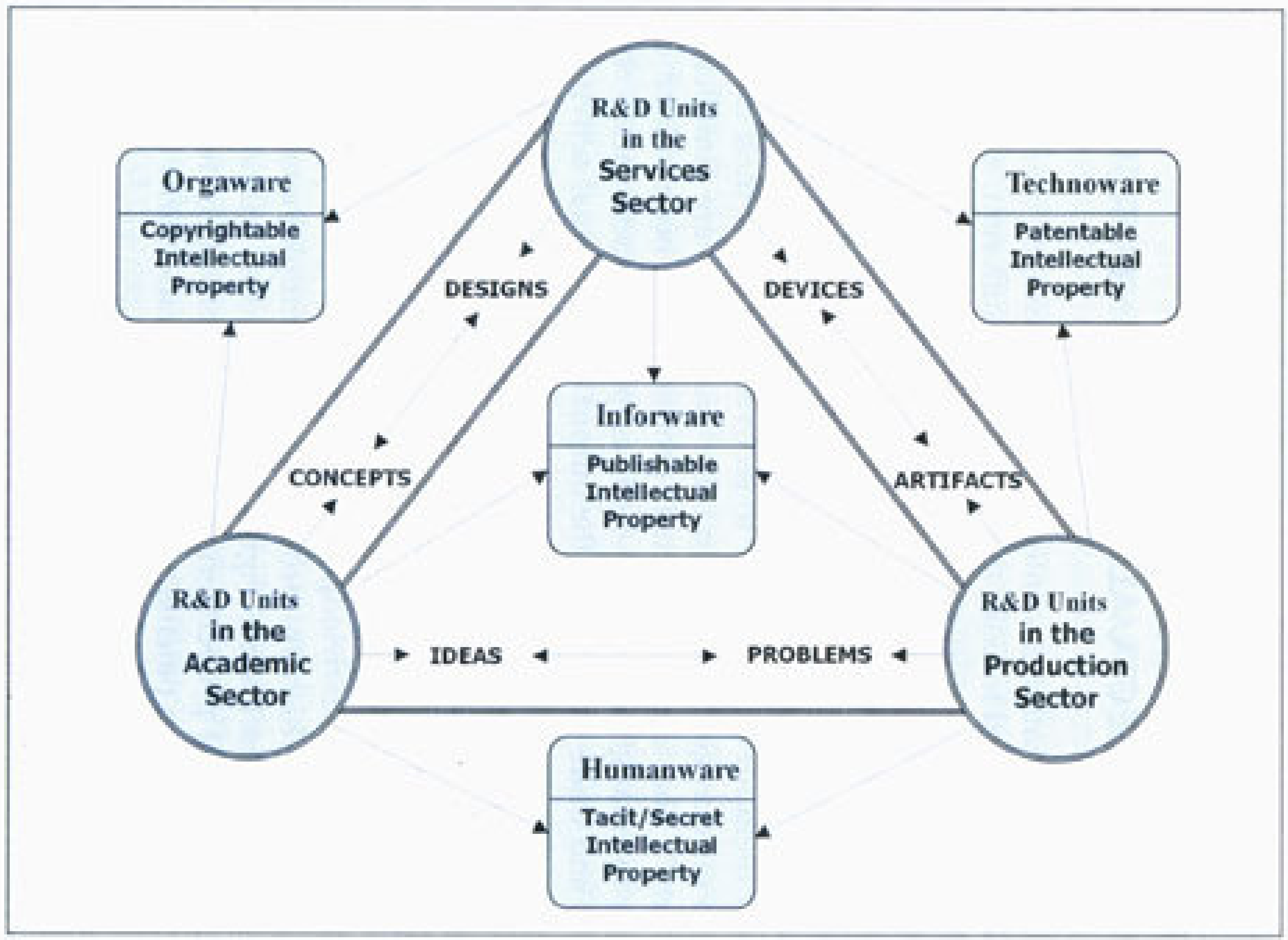

Figure 2 Triangular Linkages Underpinning Sophistication of Technology Component Innovations

The owner of a patent gets the right to exclude others from making, using or selling the invention throughout the country where it is registered. In short, others may not make, use or sell the patented innovation without the authorization of the patent owner. Patents prohibit others from making the patented item without paying royalty or licensing fees. A patent (which deals with explicit and proven knowledge) then, is a limited monopoly granted by the government for new products and processes for the term period of the patent. After the patent expires, anyone may make, use or sell the innovation. A copyright protects writings and artistic works against copying. Several classifications of works are specified under the copyright statute and include things like, literary works, dramatic works (including artistic expressions), musical works (including music and lyrics), computer programs, video recordings, etc. Many copyrights are directed to forms of expression rather than subject matter. For example, the description of an article of manufacture or a process could be copyrighted as "a writing" for preventing others from copying such a unique description. However, the copyright will not prevent others from making the article or using the process. Copyrights provide protection against commercial production of explicit and applied knowledge. A trademark relates to identification of a product by means of a name or symbol (that is not a description of the product), and which is used in the streams of commerce to identify the source or manufacturer of the product. Trademark registration provides exclusive right of the use of name or symbol. Trademark rights are based on first use in commerce and will prevent others from selling similar products using the same name or symbol, or any confusingly similar name or symbol. A trademark will not prevent others from making the same goods or products. A service mark is similar to a trademark except that it relates to the identification of a service rather than a product. Having noted the legal provisions associated with intellectual property, we move on to the concepts and requirements of the terms "intellectual capital" and "intellectual entrepreneurship."

The key element in intellectual property is opportunity for appropriability giving unique and specific ownership. However, to be recognized and protected as an intellectual property through patents and copyrights, the knowledge base for the innovation has to be in the codified form. Thus, we need to look into various knowledge forms. According to Webster's Dictionary: "Knowledge is the fact or condition of knowing something with familiarity gained through experience or through association." Thus, the term knowledge management can be interpreted as the systematic process of finding, selecting, organizing, distilling, presenting and protecting information in a way that improves comprehension and application in a specific area of innovation for transformation and management activities. In earlier days, knowledge used to be generated scientifically within a discipline, using primarily the cognitive context. Over the years we have learned that intelligence covers many cognitive skills, including the ability to solve problems, and learn and understand communications. Therefore, nowadays, knowledge is being generated in a much broader, interdisciplinary context of value addition and problem solving.

Knowledge by itself does not contribute to economic growth until it is put into profitable use. Thus, it is not knowledge generation for the sake of knowledge, but knowledge generation in the context of economic wealth creation, is our focus here. Well-documented case studies on the successes and failures of R&D projects show that scientists/researchers like "discovering knowledge" for recognition and entrepreneurs like "commercializing knowledge" for creating wealth. Furthermore, we know that knowledge sharing is a non-zero sum game, which brings in the associated problems of sharing wealth. Studies have also identified many requirements or factors that help produce intellectual capital, such as: (1) following a problem solving approach; (2) integrating innovation triangle linkage through value networking; (3) leveraging diversity for innovation based on scholarship of integration using knowledge from different cultures; and (4) informally exchanging codified and tacit knowledge. Therefore, it seems that, besides patented technoware, which we have recognized for quite some time, we can now recognize the emerging importance of knowledge-based humanware, inforware and orgaware. Production processes for goods and services (as combination of inforware and orgaware) are also patented as intellectual property. However, one has to understand the subtle differences between the tacit and explicit components of knowledge and legal provisions regarding intellectual property rights. Moreover, it appears now that orgaware produced through creative combination of new and already existing techniques is likely to open up promising application and the creation of new industries and markets. Lately we have noticed many information technology and knowledge management oriented "solution provider companies," who are producing computer software and are engaged in thriving consultancy business in this growing area. However, let us note that (unlike patented technoware), humanware, inforware and orgaware capitals (copyrights) are generally intangibles, and as such are harder to measure, harder to quantify, and harder to manage.

Stefan Kwiatkowski has given a lot of thought on intellectual entrepreneurship [End Note 6]. As explained in his papers, I agree that intellectual entrepreneurship can be simply described as putting knowledge to economic work or capitalization of intellectual property right. As I have tried to show in Figure-2, intellectual capitals manifest in technoware, humanware, inforware and also in orgaware, and are produced by effective interactions among the R&D units in all three domains (academic, production and services sectors). Interestingly, I find Kwiatkowski has aptly introduced a very useful distinction between an ordinary entrepreneur – one who is exploiting opportunities within the given operation context, and the intellectual entrepreneur – one who is creating as well as exploiting opportunities by enacting new context. We are familiar with many studies indicating that in the case of material-based (technoware) intellectual property creation, regional Science and Technology (S&T) Parks and incubators have helped to create new knowledge through exchange of codified and tacit knowledge at common places of interaction, and helped to commercialize result results. Now, in the case of non-material intellectual property creation, and in the age of Internet and mobile-organizations, one may think that there is no need to have physical proximity of S&T Park (or innovation "hot spots"), because value networks can create new knowledge. But is that so? We will discuss this issue in the next section following the role of higher education.

6. Institutions of Higher Learning and Knowledge Capitalization

Learning through education and training transforms people to have humanware (person-embodied art-of-doing-type technologies), and as I can imagine, doctoral level education enables humanware to produce inforware (record-embodied know-what-how-why-type technologies) and orgaware (activity-embodied procedural technologies). Therefore, it is my belief that institutions of higher learning (particularly those with doctoral level education programs) have to play a key role in generating and applying knowledge that can create wealth by producing highly qualified humanware, useful inforware and competitive orgaware. In the developed countries, most people now recognize that universities are in the knowledge business. Just as companies create, develop and market products, universities discover, organize, apply and deliver knowledge both in tacit (some call it soft knowledge in humanware) and codified (which is hard knowledge in inforware) forms. Thus, it is the doctoral-level degree granting universities that produce intellectual property.

In developing countries, we often overlook that education is much more than "qualification earning." It is high time that we start to renew some of our old heritages regarding education and lifelong learning. Our earlier civilizations knew it very well that students should be creative and innovative. They should be able to identify and integrate key issues in every decision situation. They should be prepared for self-development through continuous learning. Now we should add that: institutions of higher learning (particularly doctoral degree granting universities) must be focusing on generation and application of knowledge that can create wealth. However, it should be clear that new knowledge creation requires accumulation and exchange of codified as well as tacit knowledge. We generally know more than we can articulate (codify and share). Tacit knowledge is self-organized and drives our action. While tacit knowledge is transferable, it is not articulated easily. Exchange of tacit knowledge demands face-to-face contact in which people engage in a discussion or demonstration of the solution to a problem. Some tacit knowledge is "observable-in-use." Some may be acquired through emulation based on observance. Reverse engineering also enables transfer of tacit knowledge, which may be obvious and hence not codified for sharing. Therefore, to obtain tacit knowledge we need to invest in human interaction. Even though Internet enables value networking, for leveraging the intellectual capital of the world, one cannot eliminate the face-to-face interaction essential for intellectual entrepreneurship based on tacit knowledge.

Another way we can understand the importance of tacit knowledge is to note that it is in fact "wisdom." But the process of transforming knowledge to wisdom is not straightforward – it is a natural but complex human process involving integration and internalization of subject matter and perception-related knowledge. The complex process for becoming wise includes: socialization (sharing experience – from tacit knowledge to tacit knowledge – humanware development); externalization (articulating tacit knowledge – from tacit knowledge to explicit knowledge – both inforware and orgaware development); integration (synthesizing concepts – from some explicit knowledge to better explicit knowledge – both inforware and orgaware development); and internalization (gaining wisdom – from explicit knowledge to tacit knowledge – humanware development). However, real tacit knowledge depends on the knowledge base that includes both factual (typically found in documents – inforware) and heuristics (the art of doing something – humanware) aspects. And conceptualization marks the beginning of knowledge capitalization.

7. Situation in Selected Asian Countries and the Challenges They Face

The overall situation described in this section is the author's perception based on numerous studies undertaken by the Asian and Pacific Center for Transfer of Technology [Ref. 2], the Asian Development Bank [Ref. 1] and lessons learned from his mentor Dr Hyung-Sup Choi (the Founder President of the Korean Institute for Science and Technology, and a long-term Minister for Science and Technology of the Government of South Korea) [Ref. 3]. Table-1 shows the R&D expenditures and R&D personnel in the United States; and

Table-2 shows the relative distribution of doctoral degrees granted in different countries. These and much other useful information are available in the Science and Engineering Indicators [Ref. 4] published by the National Science Foundation, USA. Important statistics and analyses are also available in Reference 11. References 4, 5, 7 and 8 will provide interesting readings in support of the underpinning premises for this presentation on technological wealth creation for international market competition and multiple perspectives involved in technology innovation related decision-making.

Table 1: R&D Expenditures and R&D Personnel in the US (1999)

	Share of Total R&D Expenditures		Share of FTE R&D Personnel
	Share by Source	**Share by Performer**	**Share by Sector**
Federal Government	26.7%	7.0%	4.5%
Industry	68.5%	76.1%	82.4%
University	3.2%	13.9%	12.2%
Non-Profit Organizations	1.6%	2.9%	0.9%

	Share by Type of Work
Basic Research	16.3%
Applied Research	22.9%
Development Research	60.8%

	1973	1999
Scientists & Engineers with PhD Degree	118,000	240,000
Magnitude of Basic R&D Expenditure	$ 4.099 billion	$ 44.625 billion

Source: Science & Engineering Indicators – 2002, NSF, USA.
1999 Total R&D Expenditure = $247.0 billion
1999 Total FTE R&D Personnel = 988,700

Table 2: Earned Doctoral Degrees by Country and Specialization (1998)

Location of Doctoral University	Total in Country	S&E	B&A	Degree in US
China	6,775	5,913	862	2,378
India	4,764	1,796	2,968	1,321
Japan	6,575	4,061	1,514	152
Korea	2,484	2,095	389	780
Taiwan	907	742	165	871
USA	42,683	27,309	15,374	*

Source: Science & Engineering Indicators – 2002, NSF, USA.
*** → 28% of Doctoral Degrees Earned by Foreign Students**
S&E → Natural Sciences and Engineering
B&A → Behavioral Sciences and Agriculture

Now, taking a queue from the views expressed by Bruce Lehman [End Note 2] and Bruce Mehlman [End Note 3], if developing countries of Asia aspire to be active players in the new world economy, they have no choice but to get into the act of knowledge capitalization (creation and commercialization of intellectual capital – technoware, humanware, inforware and orgaware). This message is implicit in the statement of Donald Johnson [End Note 5]. Discussions in earlier sections of this presentation indicated that, for harnessing intellectual capital and for promoting intellectual entrepreneurship, the critical requirements are: (1) effective national innovation system with triangular linkages; (2) effective institutions of higher learning with emphasis on humanware development; (3) effective generation of doctoral degree graduates capable of producing inforware and orgaware; (4) effective utilization of "Science and Engineering Ph.D." graduates in the R&D activities producing technoware; and (5) effective incentives for entrepreneurs to commercialize intellectual capital for wealth creation in a competitive world market environment.

Not surprisingly, but unfortunately, the picture is indeed very bleak in most developing countries of Asia. The numbers are simply disheartening! While the United States (the country I have used as benchmark) produces approximately 9 Science and Engineering Ph.D.'s per 10,000 population, the corresponding numbers for Japan is 6.5, Korea is 6.75, and Taiwan is 7.5 are not so bad (they have joined the developed nations club); but those numbers for China is 0.75 and India is 0.50 only. While bulk of the R&D activities in the United States (over three quarters) are funded by the private sector (which spends money effectively!), the developing countries of Asia still depends solely on their governments for over 90 percent of their R&D expenditures (where commercialization of research results are rare, because the R&D institutions first find a solution and then look for problems to apply them!). As opposed to a healthy balance between knowledge-push and market-pull in intellectual capital creation in the developed countries, in the developing countries, there is still very little concern for market pull. Ph.D. dissertation research and R&D activities in these countries are theoretical in nature, and hence there is very little wealth creation.

It seems that the US has the correct numbers, has the correct distribution of R&D efforts, and has the right climate to attract top-grade humanware from all over the world. And yet, not being complacent, many in US have already started to assess its doctoral programs very critically. This is an indication of the recognized importance of the institutions of higher learning in creating national wealth. Because of the reluctance of many famous universities to get into the business of knowledge management, the industrial sector in the US has started to take the lead. Some say that an "ivory tower" attitude and superiority complex will lead to marginalizing the value of the premier universities. While few careful observers would say that American doctoral education is broken, they generally agree that demands on the Ph.D.'s have expanded to a point where its fundamental premises need to be re-examined [End Notes 7 and 8]. Developing countries should learn from these studies, to be forewarned and forearmed, and perhaps attempt leapfrogging when establishing their doctoral programs. It is critical to remember that "knowledge business" is the creation, evaluation, exchange and application of new ideas into marketable goods and services, leading to the economic prosperity of a nation. In addition one should note that most of the new knowledge is actually combining in new ways things that were previously discovered and applied elsewhere – which is known as recombinant innovation. Therefore, doctoral level programs in the developing countries should be producing graduates who can mix and match knowledge, borrow and adapt knowledge, and employ composite methods of real-world problem solving, using a balancing act between the knowledge-push and market-pull forces for the generation of intellectual property, which will be commercialized by the emerging "intellectual entrepreneurs."

Also let us note that problem solving is a process in which we perceive and resolve a gap between a present situation and a desired goal, with the path to the goal blocked by known and unknown obstacles. In most cases these real world problems are much greater than what an individual or one organization can solve using the knowledge in one academic discipline. Today, interdisciplinary teams are therefore engaged in solving problems that involve backward learning. Learning backward means – identifying the problems that are important, and then acquiring the explicit and tacit knowledge needed to solve them. The universities in developing countries should promote doctoral dissertation research with this problem solving orientation. Moreover, in a competitive environment, problem solving takes place under time constraints, favoring fast workable solutions over fully investigated comprehensive solutions. Therefore, the criteria for achievement should be usefulness and not elegance. In addition, in the context of globalized economies, real-world problems require our ability to deal with – ill-defined structures; time or other factors of high stress; a future that is uncertain or not predictable; and multiple players and goals that are shifting or even competing rather than complementary. Again, learning from the current experiences in the developed countries, decision-making related to real-world non-routine problem solving is mostly based on integration of available knowledge through a mental model (conceptualization). For most complex situations, people intuitively construct mental models in the form of tacit, generalized understanding of the situation and action procedures. Hence, the doctoral programs need to emphasize conceptualization for acquiring wisdom, and the problem-solving decision-making strategy should be to achieve solution through continuous improvement.

The Internet and emerging e-learning systems deliver powerful solutions for a continuum of wealth creation activities and applications – from traditional education for non-traditional students to knowledge sharing among the triangular performers of innovation systems. Intranet and wireless networks can extend online courses to some of the most highly motivated learners. It can also be used for identifying the best business opportunities by market segment, world region, and time frame. Thus, the physical infrastructure for getting into the knowledge management mode is becoming widely available. What is urgently needed is an integrated approach to using the Internet networking (for explicit knowledge) on a regular basis combined with frequent face-to-face interactions (for tacit knowledge) by the doctoral programs of national universities. I believe it is fair to say that industrialized nations do not possess a monopoly on the "ultimate source" for intellectual property – the creative human mind. Therefore, I echo the mission statement of the Intellectual Entrepreneurship Program of the University of Texas at Austin, USA to suggest that universities in developing countries, through their doctoral programs, should create spaces where intellectual entrepreneurs from inside and outside the university can gather to solve problems of wealth creation [End Note 9]. This is the greatest challenge for our universities.

End Notes

[1] **World Development Report 1998/99** of the World Bank proposed that we look at the problems of development in a new way — from the perspective of knowledge. The Report stated that: Poor countries — and poor people — differ from rich ones not only because they have less capital but also because they have less knowledge. Indeed, even greater than the knowledge gap is the gap in the capacity to create knowledge. The World Bank Report went on to suggest forcefully that expanding telecommunications hold the promise to improve every developing country's capacity to absorb knowledge for their economic development.

[2] Bruce Lehman, President of the International Intellectual Property Institute in the Viewpoint on **Intellectual Property as a Means of Wealth Creation in the Market Economies of Developing Nations**, presented at Dhaka, Bangladesh, on 22 November 1999, stated: "Majority of the people in the United States are not tilling fields, mining minerals, pumping oil or stamping machinery parts. They are producing purely 'intangible property' – what we have come to know as 'intellectual property'. The property which lies at its heart is not physical, it consists of nothing more than organized thoughts created by the human mind."

[3] Bruce Mehlman, Assistant Secretary for Technology Policy, United States Department of Commerce included the following statistics in a speech on **The Changing Wealth of Nations: Intellectual Property in the Age of Information**, delivered on 3 May 2002 at the Licensing Executives Society Spring Meeting, Washington DC:

- We generate the most patents per capita. According to Harvard Business School Professor Juan Enriquez, it takes about 3,000 Americans to generate one US patent, compared to 4,000 Japanese, 6,000 Taiwanese, 1.2 million Mexicans, 1.8 million Brazilians, 10 million Chinese and 21 million Indonesians.
- We conduct more research and development than any other nation. The United States finances 44% of the total worldwide investment in R&D – equal to the combined total of Japan, the United Kingdom, Canada, France, Germany and Italy.

[4] **The Science & Engineering Indicators 2002** has a lot of relevant statistics. According to National Science Foundation (NSF), among the OECD Countries, US R&D expenditures equal the combined total expenditures of Japan, the United Kingdom, Canada, France, Germany and Italy. US scientists and engineers produce nearly one-

third of articles published in the world's most influential technical journals. In 1999, more than 153,000 patents were issued in the US. Japan, the United Kingdom, Germany and France accounted for 70 percent of foreign-origin US patents. In 1999, Europe produced far more science and engineering doctoral degrees (54,000) than the US (26,000) or Asia (21,000). An estimated 28% of doctoral scientists and engineers at the US universities and colleges in 1999 were foreign born. The ratio of natural science and engineering degrees to the population of 24-year-olds in the US has reached 6 per 100 in 1998. In 2000, venture capital firms distributed nearly $ 90.6 billion, of which more than 45% went to IT firms.

[5] Donald Johnston, Secretary-General of the Organization for Economic Cooperation and Development (OECD) suggested a 10-point strategy including "revitalize aid to education and research. More effective aid is in the interest of us all." [Published in the OECD Observer on **Development: This Time Let's Get It Right**, 15 May 2002]

[6] Stefan Kwiatkowski; ***"Old Economy" and New Problems***; Prospects for Slow Growth in Post-socialist Countries; Tiger Working Paper Series No.15, Warsaw, February 2002, says: "A slow pace of development of Venture Capital in post-socialist countries and its weak contribution to financing start-up business enterprises is due to relative dearth of technological ideas, which could succeed in the global marketplace." Kwiatkowski, in his paper on **Intellectual Entrepreneurship – A Feature of Knowledge Economy** says: "The material world is one that is bound by necessities of survival: food, shelter, security. The non-material world is best described as a world in which information is the main engine of formation and transformation of economic factors of production. … This division fades with entrepreneur's entrance." He further says: "The entrepreneur brings in single-loop learning (adjusting to context), double-loop learning (exploiting to context), and beyond double-loop learning (enacting context)." Kwiatkowski, in his paper on **Institutions of Higher Learning – Mindful or Mindless of Yesterday Changes and Future Challenges** says: "Three levels of activity can be distinguishes within the academic ivory tower – new knowledge creation; packaging and repackaging of knowledge; and "dissemination of knowledge…. The third one is the very essence and raison d'être of any IHL."

[7] Chris Golde and Timothy Dore, ***At Cross Purpose: What the experiences of today's doctoral students reveal about doctoral education***, A survey initiated by the PEW Charitable Trust, published in January 2001 found that:

- The training doctoral students receive is not what they want, nor does it prepare them for the jobs they like.
- Many students do not clearly understand what doctoral study entails, how the process works and how to navigate it effectively.
- There is three-way mismatch between student goals, training and actual carriers. Doctoral students persist in pursuing careers as faculty members, and graduate programs persist in preparing them for carriers in research universities, despite the well-publicized paucity of academic jobs and offer to diversify the options available for doctorate-holders.

[8] Barbara Lovitts, ***Leaving the Ivory Tower***, Rowman and Littlefield Publishers, Lanham, 2001; studied the "Causes of Departure from Doctoral Study" in the United States. The study specifically reports the following:

- Roughly 50 percent of those who enter doctoral programs leave before completing degrees. Mostly ABD (all but dissertation).
- High percentage departure before dissertation research.
- About15-25 % leave after advancement to candidacy.
- Little or no difference exists between completers and non-completers in entering academic ability (GPA; Recommendation; etc.).

[9] Associate Dean of Graduate Studies and Director of the Intellectual Entrepreneurship Program of the University of Texas at Austin states: "Our vision is to create spaces where intellectual entrepreneurs from inside and outside the university can gather to solve problems."

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