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# Technology Entrepreneurs' Human Capital and Its Effects on Innovation Radicalness

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**Radical innovations transform existing markets, create new markets, and stimulate economic growth. This study investigates how the experience, education, and prior knowledge of technology entrepreneurs relate to innovation radicalness. Findings from a sample of 145 technology entrepreneurs operating within university-affiliated incubators suggest that general and specific human capital are both vital to innovation outcomes. Innovation radicalness was positively associated with formal education and prior knowledge of technology, but negatively associated with prior knowledge of ways to serve markets. This suggests a counterintuitive conclusion—the less technology entrepreneurs know about ways to serve a market, the greater their chances of using technology knowledge to create breakthrough innovations within it. Finally, we discuss configurations of human capital that are likely to bestow unique advantages in the construction of radical innovations.**

## Introduction

Innovation is of central importance to entrepreneurship (Covin & Miles, 1999; Schumpeter, 1942) and of immense interest, given that it is the primary instrument of competition for many firms (Baumol, 2002). Arguably, the most common way of defining innovation involves using an incremental versus radical framework. Pavitt (1991) describes radical innovations as revolutionary or discontinuous changes, while incremental innovations are conventional or simple extensions in a line of historical improvements. In economic terms, the impact of radical innovation is considerably more dramatic. They can transform existing markets, create new ones, and make an enormous economic contribution (Leifer et al., 2000). Although radical innovation outcomes have been empirically linked to entrepreneurship at a macro level (e.g., Baumol, 2002), how this is accomplished at a micro level of analysis is poorly understood.

Understanding how individuals create breakthrough innovations has rich theoretical and practical implications for entrepreneurship. Entrepreneurship, as a scholarly field, seeks to understand how, by whom, and with what effects opportunities to create future

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goods and services are discovered and exploited (Shane & Venkataraman, 2000). A number of studies provide evidence that aspects of an individual's human capital facilitate the recognition or development of an opportunity (Davidsson & Honig, 2003; Shane, 2000; Shepherd & DeTienne, 2005). Human capital theory posits that individuals with more or higher quality human capital will reap more desirable outcomes (Becker, 1964). However, the question of how human capital contributes to the process of enacting radical innovation has eluded most scholars. This research endeavors to fill that void by investigating how aspects of individual human capital are linked to the recognition of opportunities bearing radical innovation outcomes.

To investigate human capital and its relationship to radical innovation, we draw on prior entrepreneurship research that examines both general and specific human capital (e.g., Corbett, 2007; Dimov & Shepherd, 2005). In doing so, this article makes a number of contributions. First, we increase our understanding of the characteristics of technology entrepreneurs by examining three types of general human capital that are associated with innovation radicalness—experience depth, experience breadth, and formal education. Second, we examine specific human capital by investigating technology entrepreneurs' prior knowledge. We demonstrate how differences in prior knowledge of markets, customer problems, ways to serve markets, and technology at opportunity recognition systematically influence the radicalness of subsequent products and services.

We then explore which combinations of general and specific human capital are associated with radical innovation. By examining the configurations of technology entrepreneurs' human capital associated with high innovation versus low innovation, we hope to increase understanding about which characteristics are associated with radicalness. Further, we believe that differences in prior knowledge at opportunity recognition form knowledge configurations or *gestalts* that bestow unique advantages. Such configurations provide a more holistic picture of the factors that influence opportunity recognition. By examining knowledge configurations, we can see which elements of prior knowledge are most likely to be associated with radical innovation and learn how multivariate combinations of human capital can be used to understand the subsequent outcomes of technology entrepreneurs.

To summarize, this study investigates the types of general and specific human capital that are associated with radical innovation outcomes and how configurations of human capital might be linked to higher levels of innovation radicalness. The paper unfolds along the following lines. In the next section, we briefly review literature surrounding innovation outcomes and the entrepreneur. We then present a theoretical argument for why aspects of individual human capital will influence differences in innovation outcomes. Hypotheses related to general and specific human capital and its effects on innovation radicalness are proposed. We then report the methods and results of our empirical examination. A discussion follows and the paper concludes with implications for research and practice.

## **The Entrepreneur and the Radical Innovation Advantage**

Entrepreneurial ventures and small businesses contribute about two and a half times more innovations per employee than do large firms (Acs & Audretsch, 2003) and are responsible for the bulk of radical innovations in the economy (Baumol, 2002, 2006). Radical innovation lies at the core of new business development and long-term wealth creation (Ahuja & Lampert, 2001; Kirchoff, 1991). Despite the fact that large firms have the competencies to manage the development of new offerings, they languish in terms of emergent technology ventures and their ability to create innovation breakthroughs.

Utterback (1994) and Christensen (2000), among others, have noted how firms that dominate one generation of technology often fail to maintain leadership in the next because they have turned their attention to incremental improvements and, as a consequence, diminished their capacity to create truly new breakthroughs (Benner & Tushman, 2002; Leifer et al., 2000). Yet radical or breakthrough innovations are chief among the competitive weapons that enable firms to launch entrepreneurial ventures. Although large businesses account for nearly three-quarters of U.S. expenditure on research and development, independent entrepreneurs are more likely to account for the most fundamentally novel innovations (Baumol, 2006). Most revolutionary new business ideas, it can be argued, have been, and are likely to continue to be provided by the independent entrepreneur.

What gives individual entrepreneurs a radical innovation advantage? One explanation may be that opportunities to create radical innovation depend more on individual knowledge and initiative than on organizational processes. Baumol (2006) showed that among the most radical innovations within the last two centuries, the majority have emerged from individual entrepreneurs. Similarly, in a study of 12 radical innovation projects in large established firms, it was an individual scientist or an engineer who discovered the critical breakthrough in each case (O'Connor & Rice, 2001). Although we cannot assume the process of creating radical innovation is the same within large organizations as it is within the start-up context, the extant research suggests there is much to learn from the independent technology entrepreneur.

We believe it is the human capital attributes of technology entrepreneurs that enable them to generate the breakthrough insights that lead to radical innovations. Becker (1964) identified knowledge and experience as the major components of human capital. Technology entrepreneurs are individuals who recognize and exploit opportunities by leveraging technology knowledge and experience to create new value through the venture creation process. To shed light on *how* radical innovations are created, we use the lens of human capital theory to set forth a model of general and specific human capital and its effects on innovation radicalness.

## **Literature Review and Hypothesis Development**

The objective of this section is to review the literature and derive hypotheses that link aspects of technology entrepreneurs' human capital to the radicalness of their innovations. First, human capital theory is discussed as well as why such theory is of use in enhancing our understanding of how some individuals recognize opportunities to innovate. Well-known aspects of general human capital are reviewed and hypotheses are put forward. We then discuss specific types of knowledge shown to influence opportunity recognition and provide hypotheses specific to the prior knowledge framework used to examine technology entrepreneurs' specific human capital.

### **Human Capital and the Entrepreneur**

Two key characteristics, knowledge and experience, underlie the concept of human capital (Becker, 1964). Although prior research has examined how human factors such as the behavioral propensities (e.g., Mosakowski, 1998) and personality traits (e.g., Zhao & Seibert, 2006) of individual entrepreneurs affect entrepreneurial outcomes, little is known about the role of human capital in entrepreneurship. Becker (1964) developed the theory of human capital by extending microeconomics to a wide range of human behavior. He

popularized the idea of education and training as investments, similar to a firm's purchase of new equipment. In general, his theory contends that individuals with more or higher quality human capital will achieve more desirable outcomes. Therefore, in the present context, increased human capital improves the likelihood of opportunity recognition and persons with superior human capital will perceive a greater variety of opportunities than others. Consequently, those who perceive a greater variety of opportunities are likely to select a more radical opportunity from the opportunity set.

Recognizing opportunities is a vitally important aspect of entrepreneurship and is strongly linked to individual characteristics as suggested by Bygrave and Hofer (1991), who defined an entrepreneur as one who "perceives an opportunity and creates an organization to pursue it" (p. 14). Human capital has received accelerating attention in opportunity research, although much of the research has examined knowledge exclusively (e.g., Shane, 2000; Shepherd & DeTienne, 2005; Thorpe, Holt, Macpherson, & Pittaway, 2005). Knowledge influences the entrepreneur's ability to comprehend, extrapolate, interpret, and apply new information (Roberts, 1991). An individual's unique possession of prior knowledge creates a *knowledge corridor* that allows him or her to identify certain opportunities but not others (Ronstadt, 1988). In general, entrepreneurs will discover only those opportunities directly related to their knowledge (Venkataraman, 1997). Because knowledge is generated through an individual's unique life experiences, each person's accumulation of human capital is different. We posit that differences in general and specific human capital facilitate the discovery of opportunities bearing different outcomes.

***General Human Capital: Education and Experience.*** Education and experience are characteristics that are central to the concept of human capital (Becker, 1964). Experience encompasses work experience and other practical learning that takes place on the job, as well as nonformal education such as training. Both depth of work experience and broad experience across markets are theorized to increase human capital (Becker, 1964).

Research shows labor market experience, management experience, and previous entrepreneurial experiences are significantly related to venturing activities and positive outcomes (Bates, 1990; Gimeno, Folta, Cooper, & Woo, 1997; Robinson & Sexton, 1994). Fiet (1995) observed that previous work experiences set the context within which an entrepreneur decides whether to invest in a particular venture; in effect, accumulated experience increases alertness by providing more cues about when to take action. Vesper (1980), Case (1989), and Bhidé (2000) all concluded that the greatest number of start-up ideas come from previous employment. Shane (2003) indicated that business experience, functional experience, and industry experience are all useful for the discovery and exploitation of opportunities. Through work experience, people develop information and skills that facilitate the formulation of entrepreneurial strategy, the acquisition of resources, and the process of organizing. Experience increases a person's human capital and reduces uncertainty about the value of opportunities.

Breadth in work experience provides access to new information that facilitates opportunity recognition. Recognizing opportunities is often like solving puzzles because a new piece of information is often the missing element necessary to provide meaning or trigger an entrepreneurial conjecture (Shane, 2003). The more diverse a person's experiences, the greater number of puzzle pieces they can draw upon (Casson, 1995). People often learn about entrepreneurial opportunities through participation in markets (Casson, 1982). Further, variation in market experience provides access to different types of information that may be useful in the discovery process. Therefore, participation in more markets should increase the likelihood that a person will gain access to the information that is needed for opportunity recognition.

Delmar and Davidsson (2000) compared people who were in the process of starting a business with a randomly selected control group not starting a business and found that those in the process of venture-starting were more mobile across markets than the control group. Using a longitudinal survey, Evans and Leighton (1989) found the probability of being self-employed was higher the more job changes a person had. A number of studies have shown that the number of jobs a person has had positively influences the likelihood of self-employment (e.g., Blanchflower & Oswald, 1998; Dolton & Makepeace, 1990). Experience breadth, therefore, may be a key element of human capital among entrepreneurial founders.

Education is another aspect of a person's human capital that may be valuable in the discovery and exploitation of opportunities. Education increases a person's stock of information and skills, including those needed to recognize and pursue an entrepreneurial opportunity successfully. Baum, Locke, and Smith (2001) examined the performance of Canadian biotechnology firms and showed founders with master's degrees or higher had faster employment and revenue growth than others in the sample. Numerous studies examining human capital have accepted the notion that "more is better" and used formal education or years of schooling as a measure of human capital (e.g., Bruderl, Preisen-dorfer, & Ziegler, 1992; Cooper, Gimeno-Gascon, & Woo, 1994; Gimeno et al., 1997). However, the findings for a positive association between education and venture creation (Bates, 1990; Evans & Leighton, 1989), as well as between education and the discovery and exploitation of opportunities (Davidsson & Honig, 2003), have been mixed. Dimov and Shepherd (2005) suggest that a possible explanation for these mixed results is that broad measures have insufficient sensitivity to capture the impact that human capital may have on differing entrepreneurial outcomes.

To summarize, technology entrepreneurs who have greater depth and breadth of professional experience, as well as higher formal education, will have a greater ability to identify opportunities with radical outcomes. Therefore:

**Hypothesis 1a:** Technology entrepreneurs' experience depth is positively related to innovation radicalness.

**Hypothesis 1b:** Technology entrepreneurs' experience breadth is positively related to innovation radicalness.

**Hypothesis 1c:** Technology entrepreneurs' formal education is positively related to innovation radicalness.

***Specific Human Capital: Types of Knowledge.*** Scholars have begun the laborious task of investigating specific types of knowledge, or human capital, and their influence on opportunity recognition and venture creation. Christensen and Peterson (1990) conducted one of the earliest empirical studies of knowledge and opportunity recognition. Their research stressed the importance of technology and market knowledge as prerequisites for recognizing opportunities. Christensen and Peterson viewed opportunity recognition as a problem-solving process that calls on both kinds of knowledge. Their research suggests that technology and market knowledge allows for individuals to identify both problems and potential opportunities to solve problems with technology. Numerous other research studies from the new product development literature emphasize the role of specific and divergent knowledge types in recognizing and developing opportunities (e.g., Iansiti, 1993; Leonard & Sensiper, 1998; O'Connor & Veryzer, 2001).

Amabile (1999) stressed combining market knowledge and technology knowledge as advantageous for developing new ideas. She argued an individual's creativity is enhanced



if his or her cognitive style facilitates the ability to link divergent knowledge types. The group dynamics of different ideas coming together and undergoing constructive criticism to develop new products is often referred to as *creative abrasion* (Leonard & Sensiper, 1998; Leonard & Straus, 1997). This process is enhanced when individuals within the group provide different types of knowledge (Amabile, 1999; Leonard & Sensiper; O'Connor & Veryzer, 2001). Shane (2000) demonstrated, in a landmark embedded case study examining technology entrepreneurs exposed to an MIT invention, that major dimensions of prior knowledge were required and combined with technology knowledge to facilitate opportunity recognition. These include prior knowledge of ways to serve markets, prior knowledge of customer problems, and prior knowledge of markets.

Prior knowledge of how to serve markets entails how technologies can be packaged to meet the needs of a particular market. Aldrich and Wiedenmayer (1993) demonstrated the product or service lines entrepreneurs establish are related to the organizational units for which they previously worked. For example, Shane (2000) demonstrated an entrepreneur who had experience in machine design would package the potentially profitable technology via a machine rather than a service. Further, another entrepreneur could only discover the service market because of a lack of knowledge in the areas of machine design and manufacturing. In another situation, a company founder had prior knowledge of how to serve a market that required the product to be packaged in a way that would meet government approval. Because of the entrepreneur's pharmaceutical experience, he knew how to package the technology using different materials into a machine meeting Food and Drug Administration (FDA) approval (Shane, 2000).

Prior knowledge of customer problems involves information about customer needs. The locus of innovation often lies with the users because they cannot easily articulate their needs for undeveloped solutions (Von Hippel, 1988). An accurate understanding of user needs has been shown to be essential to successful new products. When individuals lack familiarity with customer problems, it is difficult to identify solutions to those problems when they are presented (Roberts, 1991). Thus, the process leads entrepreneurs to engage in start-ups to solve customer problems they learned about in their experiences (Von Hippel). For example, Shane (2000) found an entrepreneur's experience working with clinical pharmacology customer problems allowed him to see how a technology could be used to treat hypertension. Von Hippel (1986) encouraged learning from lead users as an excellent source of novel products. Lead users of products and services face needs that are common to a marketplace—but face them months or years in advance of most market participants. Since these users are aware of future problems before other users, potential entrepreneurial opportunities may be perceived that are less obvious to the general population.

Prior knowledge of markets involves information about how particular markets operate. Von Hippel (1988) indicated that prior knowledge of markets may include information about relationships with suppliers and customers, sales techniques, and capital requirements, which are likely different across markets. Possession of prior industrial knowledge about how a product or a technology influences a particular market can enable one to identify an entrepreneurial opportunity (Roberts, 1991). Market knowledge is not likely to be publicly known but can be acquired by having worked in a particular market as a manufacturer, customer, employee, or supplier (Shane, 2000). For example, Shane demonstrated that in all eight of his examined opportunities, the entrepreneurs had previous experience in the market that allowed them to see a new business application for a given technology.

In Shane's (2000) study of prior knowledge and opportunity recognition, the technology entrepreneurs he examined had knowledge of ways to serve markets, customer

problems, and markets, which were combined—or *mixed*—with new knowledge of technology resulting in their opportunity. That is, the identified prior knowledge types were antecedents to the technology. An alternative approach involves beginning with a novel technology that is suspected to have value and then search for an application. By taking the view that opportunities may be developed (e.g., Ardichvili, Cardozo, & Ray, 2003; De Koning, 2003), an individual may begin with technology knowledge and add other types of knowledge to facilitate the process. Recognizing opportunities is a learning process (e.g., Corbett, 2007; Lumpkin & Lichtenstein, 2005) and knowledge types represent building blocks that vary in the construction of an entrepreneurial opportunity. Therefore, if one views opportunity recognition as a knowledge-based process, it will begin with a mix of prior knowledge types and call on additional knowledge to facilitate the process. These prior knowledge types include: (1) ways to serve markets, (2) customer problem, (3) markets, and (4) technology. Given these knowledge types are conducive and necessary to recognize opportunities, a person who has more or higher quality will be aware of a greater variety of opportunities. Therefore, those who perceive a greater variety of opportunities are better able to select and exploit opportunities bearing more radical outcomes. This logic leads to the following four hypotheses:

**Hypothesis 2a:** Technology entrepreneurs' prior knowledge of ways to serve markets is positively related to innovation radicalness.

**Hypothesis 2b:** Technology entrepreneurs' prior knowledge of customer problems is positively related to innovation radicalness.

**Hypothesis 2c:** Technology entrepreneurs' prior knowledge of markets is positively related to innovation radicalness.

**Hypothesis 2d:** Technology entrepreneurs' prior knowledge of technology is positively related to innovation radicalness.

***Configurations of General and Specific Human Capital.*** As the previous discussion suggests, different types of human capital are likely to influence opportunity recognition processes. Studies of both the individual-level (e.g., Zhao & Seibert, 2006) and firm-level (Miller, 1988) phenomena indicate that multivariate combinations of factors are often needed to accurately account for entrepreneurial outcomes. Thus, configurations of human capital attributes may provide the best predictors of innovation radicalness. In terms of general human capital, for example, higher levels of formal education have been associated with greater open-mindedness and receptivity to innovation (Kimberly & Evanisko, 1981). For many types of entrepreneurial founders, greater experience is associated with higher levels of success (Singer, 1995). Combinations of high experience and education would therefore seem favorable for radical innovation. But greater experience has also been found to limit strategic flexibility (Hitt & Barr, 1989), which may inhibit innovation radicalness. Bhidé (2000) suggests that, in general, very high levels of human capital limit the propensity of entrepreneurs to take risks on innovative new ventures.

To address these contrasting conclusions, this study asks what configurations of general and specific human capital are associated with radical innovation. Rather than propose specific configurations, however, our aim in this part of the analysis is explore which human capital attributes are most likely to be associated with innovation radicalness. In the next section, therefore, we extend what has been a partial understanding of human capital and investigate how differences in general and specific human capital are related to different innovation outcomes. Then, we conduct supplementary analysis to

address what configurations of general and specific human capital are most strongly associated with innovation radicalness.

## Methods

### Sample

To identify founders of technology ventures who recently started a venture, technology incubators were targeted. An incubator is a facility designed to encourage entrepreneurship and minimize obstacles for new venture formation and growth by housing a number of fledgling enterprises that share an array of services. A list of incubators in the central United States was obtained from the National Business Incubation Association online database. Incubators were selected based on proximity to a large Midwest university and the number of technology ventures housed there. All of the incubators enlisted were affiliated with universities although not necessarily university-owned. In total, 13 incubators took part in the study, which resulted in individual meetings with founders during which the survey was completed. The sample consisted of 145 technology entrepreneurs throughout the Midwest. Of the respondents, 92% were male and 8% female. The average number of years of professional work experience was about 20 years and the average number of different employers worked for was approximately four. Among the respondents, 40% were PhDs, followed by about 33% who held a bachelor's degree and 26% who possessed a master's degree. About 3% held an associate's degree and fewer than 2% had only a high school education.

### Survey Instrument

The survey used in this study included two experience items, an education item, 20 prior knowledge items, and 10 items concerning the innovativeness of technology entrepreneurs' products or services. The items used to examine entrepreneurs' prior knowledge at opportunity recognition were developed from the constructive prior knowledge framework and addressed the amount and importance of prior knowledge at opportunity recognition. Items addressing characteristics of the venture and other founder demographics were also included.

### Scale Development and Content Validity

For the purposes of the study, four prior knowledge scales and an innovation scale were developed. In both cases, deductive scale development was employed. Deductive scale analysis requires an understanding of the phenomenon being investigated and a thorough review of the literature to tap the construct of interest (Hinkin, 1995). *Degree of radicalness* is often used to classify innovations according to how radical they are compared with existing products or services (Freeman & Soete, 1997; Hage, 1980). This way of differentiating between radical and incremental innovation is useful for defining a continuum of innovation types and, therefore, a group of items was also derived to assess the radicalness of products and services using Hage's (1980) and Leifer et al.'s (2000) work distinguishing among incremental and radical innovation.

Researchers derived a group of items for the prior knowledge constructs using the reviewed literature and quotes from the entrepreneurs in Shane's (2000) embedded case study.



After the generation of items, the prior knowledge items were then subjected to a content validity assessment by eight faculty members and doctoral students who were asked to classify each item to one of five categories, which included the four prior knowledge dimensions plus an *other* category. Those items that were assigned to the intended category more than 85% of the time were included in the survey instrument. Experts in scale development from a Research 1 University's Survey Research Laboratory were consulted throughout construction of the items and scales.

## **Pilot Testing**

A pilot study ( $n = 15$ ) was conducted using technology entrepreneurs affiliated with a large Midwestern university. The pilot was used to identify any unclear items, problematic directions, the length of time required to complete the survey, and to determine a workable data collection protocol. No problematic items or instructions were found and the average length of time to complete the survey was approximately 20 minutes.

## **Data Collection Procedures**

Incubator managers were identified using the incubator's representative website and were contacted by phone. The manager was provided with an overview of the research initiative and asked to provide contact information of founders of technology-based ventures that were approximately 5 years old or younger. In all cases, the manager provided names and contact information of founders of technology-based ventures at their site. The identified entrepreneurs were contacted and asked to participate in a research project funded by the Kauffman Foundation and the sponsoring university. The entrepreneur was informed the results of the study may be used to improve entrepreneurship education. The entrepreneur was questioned to assure they were the individuals responsible for the venture idea. If they were not responsible for the venture idea they were not asked to continue. If the contact was the person responsible for the venture idea, a 30-minute meeting was requested. Of the entrepreneurs contacted, only one elected not to participate and approximately 10 were unable to meet with the researcher because of prearranged travel plans. In exchange for their participation, the entrepreneur was presented with a book in appreciation for their time in completing the survey. The entrepreneur was also asked to pay close attention to the delineation of time in the survey as it contained items about their prior knowledge when they first perceived their opportunity, followed by items that concern the present.

## **Measures**

***General Human Capital Independent Variables.*** To assess general human capital, three items were used to determine the experience and education of the technology entrepreneurs. Breadth of experience was measured using an item that questioned the number of employers the entrepreneur had worked for. To measure the depth of experience, the number of years of professional work experience was requested. The education item used an ordinal scale and requested the respondents' highest level of education. The scale included high school, associate degree, bachelor's degree, master's degree, and PhD.

***Construction of the Specific Human Capital Independent Variables.*** There were initially five items for each prior knowledge type specific to the time the opportunity was first

Table 1

### Summary of Prior Knowledge Scored Variables

Prior knowledge	$\bar{A}$	SD	$\bar{I}$	SD	$\bar{P}$	SD
Ways to serve markets	13.26	4.39	9.54	1.87	33.69	14.73
Customer problems	12.90	4.24	9.54	1.84	32.46	13.51
Markets	11.02	4.19	8.65	2.16	25.07	12.52
Technology	14.47	4.65	9.27	2.11	35.69	15.82

$\bar{A}$ , prior knowledge amount mean;  $\bar{I}$ , prior knowledge importance mean;  $\bar{P}$ , prior knowledge variable mean

recognized. Following each item, two Likert-type response scales were included, one that addressed the *amount* of prior knowledge and a second that inquired about its *importance* to perceiving the opportunity. The *amount* response scale used a 5-point Likert-type scale and the *importance* response scale used a 3-point Likert-type scale. Opportunity recognition was assumed to be a function of both a person's stock of knowledge (Ronstadt, 1988; Shane, 2000) and a person's alertness (Kirzner, 1973) to that knowledge. The *amount* ( $A$ ) and *importance* ( $I$ ) response scores were weighted by multiplying the two scores for each item together. The weighted scores for each prior knowledge type were then summed and resulted in a prior knowledge variable score ( $P$ ).

$$P = \sum_{i=1}^n A_i I_i$$

Table 1 includes the mean scores for the amount of prior knowledge, the importance of that prior knowledge, and the resulting prior knowledge variable. Technology entrepreneurs scored the *amount* of their prior knowledge of technology the highest followed by ways to serve markets, customer problems, and markets. The respondents scored the *importance* of their prior knowledge to recognize the opportunity as customers problems the highest followed by ways to serve markets, technology, and markets. Of the four prior knowledge variables, technology knowledge at opportunity recognition scored the highest, followed by ways to serve markets, customer problems, and markets.

**Prior Knowledge Scales.** Prior knowledge items made up scales that were used to assess prior knowledge of (1) ways to serve markets, (2) customer problems, (3) markets, and (4) technology. A principal components factor analysis with varimax rotation was performed to determine factor loadings (Table 2). Four of the five items for each prior knowledge type achieved a factor loading of .40 or greater and were thus considered to measure the construct of interest and retained as recommended by Hinkin (1995). The prior knowledge response scales of both *amount* and *importance* used to comprise the prior knowledge variables were found to be reliable overall, as each obtained alpha coefficients of between .68 and .89. Coefficient alpha assesses how well the set of items measures a single unidimensional construct.

Table 2

Factor Structure of the Prior Knowledge Scales

Item	Ways to serve markets	Customer problems	Markets	Technology
My hands-on experiences in creating products/services similar to my forthcoming business.	.74			
My knowledge of ways to produce products/services similar to that of my forthcoming product/service.	.68			
My knowledge of products/services similar to that of my forthcoming business.	.62			
My knowledge of specific standards that my forthcoming product/service would need to meet.	.53			
My knowledge of different customers' problems that my forthcoming business could help with.		.74		
My knowledge of ways customers use products/services similar to that of my forthcoming business.		.68		
My first-hand interactions with customers similar to that of my forthcoming business.		.68		
My knowledge of lead customers similar to that of my forthcoming business.		.63		
My knowledge of suppliers in the primary market of my forthcoming business.			.83	
My knowledge of manufacturers or developers in the primary market of my forthcoming business.			.79	
My knowledge about the market of my forthcoming business not known to the general public.			.72	
My knowledge about how the market functions of my forthcoming business.			.57	
My knowledge of a specific technology important for my forthcoming business.				.83
My knowledge of a technology that is central to my forthcoming business.				.81
My knowledge of a technology not known to the general public.				.78
My hands-on experiences with a technology that is important for my forthcoming business.				.77
Amount scale Cronbach's alpha	.79	.84	.89	.83
Importance scale Cronbach's alpha	.68	.70	.79	.81

**Construction of the Innovation Dependent Variable.** The dependent variable was an innovation score initially based on a 10-item scale. The 10 items used a 4-point Likert-type level of agreement response scale to determine the radicalness of the product or service. A 4-point response scale was used, as even-numbered scales can more effectively discriminate between agreement or disagreement because there is no neutral option (Dillman, 2000). The scale used a progressive hierarchy where higher scores indicated products or services more radical in nature while a lower score indicated incremental or feature improvements. Several of the items were worded in such a way as to warrant reverse coding and used to prevent patterned responses.

**Innovation Scale.** A principal components factor analysis with orthogonal rotation was performed to determine factor loadings. Seven of the 10 items achieved a factor loading of .40 or greater and were thus considered to measure the construct of interest (Hinkin,

Table 3

Factor Loadings of the Innovation Scale

Item	Radicalness
There is a large group of customers that already uses a very similar product/service.	.73
Our product/service represents an entirely new type of product/service.	.73
Our product/service may be described as a new technology.	.67
Our product/service is a gradual progression upon the last generation.	.55
Our product/service could be described as a product line extension.	.55
Our product/service meets a want or a need that has not been addressed by other products/services.	.55
Our product/service is a new twist on an old theme.	.44
Cronbach's Alpha	.71

1995). The resulting 7-item scale was found to be reliable with a resulting coefficient alpha of .71. The responses to the retained seven items were used to create the innovation dependent variable (see Table 3).

**Control Variable.** A number of studies have indicated differences between the age of a venture and outcomes. For example, Quinn and Cameron (1983) showed criteria for effectiveness change as new organizations develop. Utterback (1994) indicated the extent of innovation exercised was also, in part, a function of age. The regression performed employed a single control variable—age of venture. The control variable was created by calculating the number of months between venture launch and the date the survey was completed.

Results

Nine variables were used within the study and included three general human capital variables, four specific human capital variables, an innovation variable, and a single control variable. The general human capital variables included (1) depth of experience, (2) breadth of experience (number of employers worked for), and (3) formal education or degree. The specific human capital measures were prior knowledge variables that included (1) ways to serve markets, (2) customer problems, (3) markets, and (4) technology. Table 4 provides descriptive statistics and correlations across the variables.

Hierarchical multiple regression was used to determine the human capital variables most strongly associated with the innovation variable (Table 5). The analysis used three models comprising the control variable, the set of general human capital variables, and the set of specific human capital variables. The base model (Model 1) included only the effect of the control variable (i.e., age of venture) and explained minimal variance ( $R^2 = .01$ ). To assess general human capital, depth of experience, breadth of experience, and formal education were introduced as a step change in Model 2. The set of general human capital variables explained a statistically significant portion of variance in the innovation variable ( $R^2 = .11$ ;  $p < .01$ ). The set of specific human capital variables comprising prior knowledge types was introduced as a step change in Model 3 and explained a significant portion of variance over Model 2 ( $R^2 = .08$ ;  $p < .05$ ). Therefore, the general and specific human capital variable sets collectively explain a statistically significant portion of variance ( $R^2 = .20$ ;  $p < .01$ ).

Table 4

Descriptive Statistics and Inter-correlation Matrix

Variables	Mean	SD	1	2	3	4	5	6	7	8
1. Innovation	20.37	3.85								
2. Experience depth	19.52	9.95	.16							
3. Experience breadth	3.94	2.74	.03	.32**						
4. Formal education	3.94	.97	.28**	.10	-.11					
5. Ways to serve markets	33.69	14.73	-.16	.09	-.02	-.24**				
6. Customer problems	32.46	13.51	-.13	.03	-.05	-.15	.57**			
7. Markets	25.07	12.52	-.07	.14	.05	-.19*	.44**	.60**		
8. Technology	35.69	15.82	.16	.07	-.12	-.04	.41**	.20**	.18*	
9. Age of venture	42.07	30.36	.07	.13	-.04	.14	.14	.03	-.15	.19*

\*  $p < .05$ , \*\*  $p < .01$

Table 5

Regression Results for Human Capital and Innovation

Variables	Model 1		Model 2		Model 3	
	Beta	<i>t</i>	Beta	<i>t</i>	Beta	<i>t</i>
Control						
Age of venture	.11	1.23	.07	.76	.06	.67
General human capital						
Experience depth			.15	1.62	.16	1.72*
Experience breadth			.02	.25	.04	.67
Formal education			.28	3.26***	.22	2.50**
Specific human capital						
Ways to serve markets					-.23	-2.06**
Customer problems					-.04	-.37
Markets					.02	.20
Technology					.26	2.73***
Model's R <sup>2</sup>		.01		.12***		.20***
Change in R <sup>2</sup>		.01		.11***		.08**

\*  $p < .10$ , \*\*  $p < .05$ , \*\*\*  $p < .01$

The full model reveals that of the general human capital variables, formal education was statistically significant ( $p < .01$ ) and depth of experience was marginally significant ( $p = .09$ ). The breadth of experience variable was not significant in the variance explained. Of note, all the general human capital variables exhibited positive betas in relationship to innovation radicalness, although the experience breadth variable was negligible. Therefore, of the general human capital hypotheses, hypothesis 1a is partially supported and hypothesis 1c was supported. Hypothesis 1b is not supported.



The full model shows that of the specific human capital variables, prior knowledge of technology was statistically significant ( $p < .01$ ), as well as prior knowledge of ways to serve markets ( $p < .05$ ). However, contrary to hypothesis 2a, the standardized beta coefficient indicated a negative correlation between prior knowledge of ways to serve markets and innovation radicalness; prior knowledge of technology was in the hypothesized direction. Neither the prior knowledge of customer problems nor the prior knowledge of markets variables explained significant portions of variance, although interestingly, prior knowledge of customer problems also had a negative beta. Hence, of the specific human capital hypotheses, only hypothesis 2d was supported.

## Supplementary Analysis

To explore how differences in human capital translate to different innovation outcomes, a configuration analysis was developed. These emergent configurations represent the relative arrangements of human capital that resulted in incremental versus radical innovation. To construct configurations for incremental versus radical innovation, the innovation variable was used to create two groups of cases which included a *high group* ( $n = 22$ ) typifying radical innovation that scored 1 standard deviation (SD) above the innovation variable mean and a *low group* ( $n = 22$ ) typifying incremental innovation that scored 1 SD below the innovation variable mean. Human capital variables were plotted along the x-axis, mean scores were plotted along the y-axis, and high and low innovation lines were displayed within the plot area. The general human capital variable scores were first standardized and then the variable means were plotted for high and low innovation as seen in Figure 1. The specific human capital configurations appear in Figure 2.

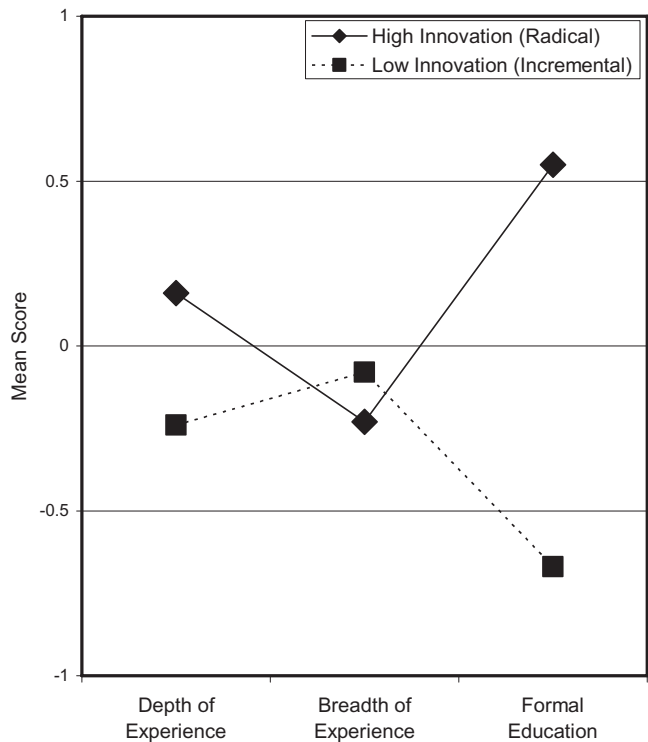
The general and specific human capital configurations appear overall consistent with the hierarchical regression results. However, the patterns reveal the relative arrangements of human capital types for differing innovation outcomes. For the general human capital configurations, the greatest difference between the innovation groups was among formal education and depth of experience—both of which were positively associated with innovation radicalness. The specific human capital configuration showed that prior technology knowledge *alone* was greater for more radical innovation outcomes. While the two configurations showed a similar pattern, the greatest difference among the two groups was prior knowledge of technology and ways to serve markets. Prior knowledge of ways to serve markets was considerably less for those technology entrepreneurs who created more radical products or services.

## Discussion

The purpose of this study has been to investigate how the human capital of technology entrepreneurs relates to innovation radicalness. Overall, the results support previous research that highlighted the importance of individual differences in human capital and opportunity recognition (Davidsson & Honig, 2003; Ronstadt, 1988; Shane, 2000; Shepherd & DeTienne, 2005). The current study provides evidence that aspects of both general and specific human capital are vital to explaining radical innovation. Consistent with Becker (1964), general human capital was positively correlated with a highly desirable outcome—breakthrough innovation. Formal education and experience depth were positively and significantly associated with radical innovation, although formal education was more significantly related. These findings suggest that education level and deep

Figure 1

General Human Capital Configurations for Innovation



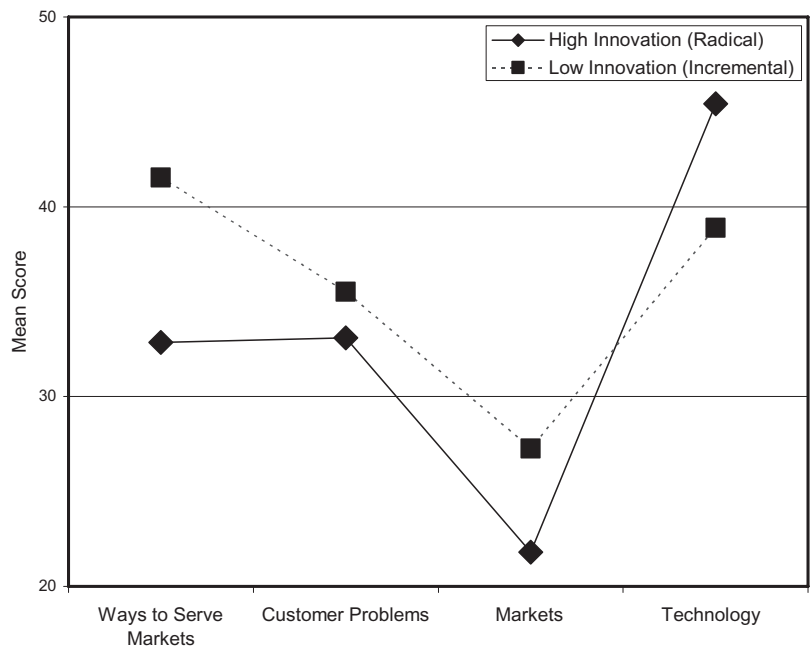
knowledge based on years of experience are more important for creating breakthrough innovation than broad experience across multiple areas.

For specific human capital, the findings underscore the vitality of prior technology knowledge at opportunity recognition to create radical innovation. However, the results are somewhat inconsistent with human capital theory and bring an interesting finding to light. Becker’s (1964) theory contends that individuals with more or higher quality human capital will reap more desirable outcomes. Instead, the current study strongly suggests that it may be more favorable to possess less of particular types of knowledge to achieve breakthrough innovations—which represent highly desirable outcomes. Prior knowledge of ways to serve markets and technology knowledge were the best predictors of innovation. However, the results are curiously counterintuitive—while technology knowledge was positively correlated with innovation radicalness, knowledge of ways to serve markets was negatively correlated. This suggests that knowing *less* about ways to develop and package a future product or service at discovery may be advantageous for creating frame-breaking innovations. Individuals who know less about customer problems and lack knowledge of ways to serve them, yet have heightened technology knowledge at discovery, appear best positioned to create breakthrough innovations.

Interestingly, the specific human capital knowledge configuration (Figure 2) reveals that, of the different knowledge types at opportunity recognition, only technology knowledge was greater for those entrepreneurs who created radical innovations. The knowledge configuration and the negatively correlated betas of prior knowledge of ways to serve

Figure 2

Specific Human Capital Configurations for Innovation



markets and prior knowledge of customer problems provide evidence that these knowledge types may stifle creativity and recognizing more radical opportunities. These findings concur with Bhidé’s (2000) assertion that too much human capital can limit the propensity of entrepreneurs to pursue more risky ventures. An explanation may be that overfamiliarity with customers, markets, and development standards constrain recognition or exploitation of opportunities with breakthrough potential. High knowledge of development standards and market practices may lead to preconceived notions of the possibilities and limit the opportunities considered and developed. Considerable knowledge of the accepted standards and behaviors of customers may precondition a person to dismiss potential opportunities with radical outcomes and therefore severely limit his or her opportunity set. A person who is not conditioned to the accepted norms of customers, markets, and common development processes, but who has rich technology knowledge, may be best positioned to recognize, develop, and exploit opportunities with breakthrough potential.

Our study suggests that the reasons why entrepreneurs have had, and will likely continue to have, a radical innovation advantage include (1) their rich technology knowledge, and (2) their ability to act creatively without being constrained by current customers and norms of existing products or services. Based on this, it is reasonable to conclude that the “Achilles heel” of the large firm may be a myopic view of existing customers and market norms. Christensen (2000) showed how firms that dominate a market often fall prey to new ventures that use new or existing technologies in dramatically different ways—even though they listened to their customers. Therefore, an opportunity that results from technology knowledge suspected to have value and

learning about potential demand side applications seems most indicative of the process of creating breakthrough innovation.

Taken together, the evidence suggests that individuals with greater depth of experience and higher levels of education are better suited for recognizing opportunities with highly desired innovation outcomes. Heightened knowledge of technology is also imperative to recognizing breakthrough innovations. The prior knowledge constructs identified by Shane (2000)—ways to serve markets, customer problems, and markets—were relatively less likely to be associated with innovation radicalness. Therefore, technology knowledge is a prerequisite for recognizing opportunities with radical innovation outcomes and should be included in future knowledge frameworks in the context of technology entrepreneurship.

## **Limitations**

There are several methodological limitations that should be taken into account when interpreting the results. First, a purposive sample of technology entrepreneurs whose venture was housed in incubators within the Midwest was used rather than a completely random sample. Therefore, the results may not generalize to technology entrepreneurs operating without the support of an incubator or operating in incubators outside of the Midwest or other countries. Some biases may also exist in those who select to be housed in an incubator or in the selection of incubation candidates. Second, the study called for entrepreneurs to recall broad aspects of their knowledge at a point in time in the past. People's ability to recall the past is limited, but keeping recall simple and relating recall to major life events helps produce higher quality survey data (Dillman, 2000; Huber & Power, 1985). We believe the events the technology entrepreneurs were asked to recall likely constituted major life events (i.e., recognizing the opportunity for their future venture); nevertheless, it is a potential limitation of the study. Third, the study employed subjective measures to assess the radicalness of technology entrepreneurs' product or service. That is, technology entrepreneurs rated aspects of their own venture's offering, which they may have scored as more innovative than they actually were. However, prior research indicates that objective and subjective assessments tend to correlate significantly and therefore subjective measures can be reliably used when objective measures are not available (Dess & Robinson, 1984). Further, Jennings and Young (1990) compared subjective and objective measures of product innovation and found no significant difference between the measures. Lastly, the measures employed to examine depth and breadth of experience were broad approximations and may insufficiently account for these important aspects of human capital. Future measures may better enhance understanding of these important dimensions of experience and their affect on outcomes.

## **Future Research**

Our study provides evidence that both general and specific human capital are useful for understanding the radicalness of technology entrepreneurs' products or services. While innovation, and particularly radical innovation, is a suitable dependent variable (Baumol, 2002; Fiet, 2002; Shepherd & DeTienne, 2005), future research should consider other entrepreneurial outcome variables to better understand the role of human capital. Another promising area of entrepreneurship research relates to learning outcomes of opportunity recognition (e.g., Van Gelderen, Van Der Sluis, & Jansen, 2005) and how different types of human capital enhance learning. For example, the current study raises

questions about the role of human capital subsequent to opportunity recognition. What knowledge is acquired between the time an opportunity is recognized and a venture is launched and how do these differences impact the founding and early growth of a new venture? Further, how do the knowledge configurations of technology entrepreneurs change, if at all, as the venture matures? Answering such questions may enhance our understanding of how learning influences venture creation and generates desirable venture outcomes.

While the focus of our undertaking was to examine the effects of human capital on innovation radicalness, the findings lead us to question if it is possible that innovation can be *too radical*? By too radical, we mean a product or service too far ahead of its time to gain initial sales and penetrate markets. It is suspected a relationship may exist between innovation radicalness and sales in the shape of an inverted *U*. Although we lack the data to accurately resolve this question, we encourage future studies to address the seemingly contentious relationship among radicalness and market acceptance—or sales.

## Conclusion

In conclusion, this study contributed to one of the most important questions facing entrepreneurship research today, namely, why some people, and not others, recognize opportunities, and with what effect (Shane & Venkataraman, 2000). The study responded directly to this fundamental, yet unresolved, question. The findings underscore the importance of both general and specific human capital and demonstrated how the characteristics and knowledge configurations of technology entrepreneurs are associated with differences in innovation outcomes.

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