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Creating a university technology commercialisation programme: confronting conflicts between learning, discovery and commercialisation goals

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Abstract: Our knowledge-based society is pressing universities to transform from monastic scholarly enclaves into producers of new technologies and incubators of start-up firms. However, converting scientists' curiosity-driven discoveries into commercially viable innovations has proven so difficult that observers liken the journey to crossing a 'Valley of Death'. We conceptualise the challenges of commercialising university inventions in terms of three gaps: the *technology discovery gap*, the *commercialisation gap*, and the *venture launch gap*. We chronicle the inception and evolution of a technology commercialisation programme at the University of Oregon, relating how the university confronted and dealt with the three gaps, and describing the intra-organisational partnerships developed to address them. We find that negotiating the gaps requires assimilation of a technology commercialisation mission into the traditional academic missions of education and scientific discovery. To do this, universities must confront fundamental contradictions between learning, discovery, and commercialisation.

Keywords: university technology commercialisation; technology transfer; multidisciplinary education; university spinouts; regional economic development.

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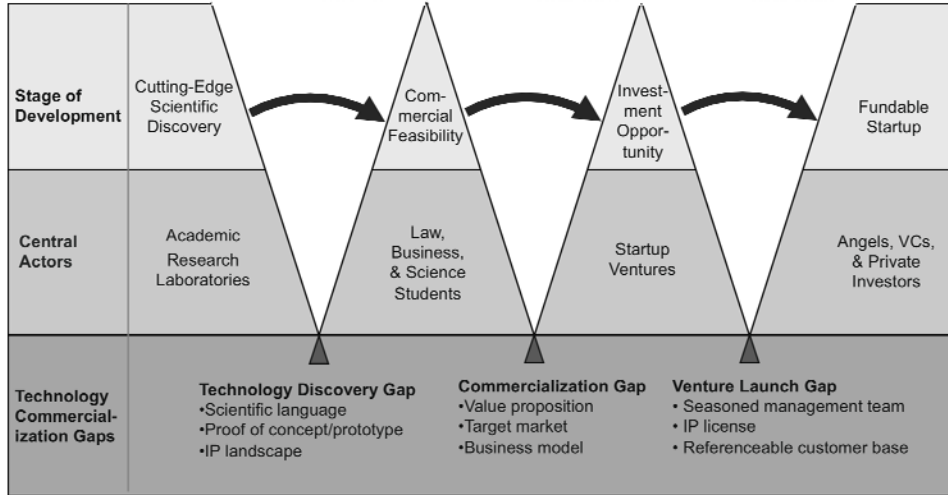
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1 Introduction

Innovation and economic development have grown dependent upon knowledge resources, sparking a transformation in the role of research universities (Etzkowitz et al., 2000). Universities are increasingly expected to contribute directly to technological innovation, incubate start-up firms, and play a role in regional economic development. In response to these rising expectations, universities are undertaking initiatives to promote the commercialisation of the technologies developed in their laboratories (Bercovitz and Feldmann, 2006).

However, the path from laboratory research findings to marketable products is full of twists and turns and often ends in failure (Cooper and Kleinschmidt, 1987; Henderson and Clark, 1990). Scholars recognise that shepherding technology down the path from lab to market is inherently risky (Ziamou, 2002). Policy makers agree and have adopted the term 'Valley of Death' to underscore the funding gap facing entrepreneurs seeking to transform scientific inventions into commercial innovations. Auerswald and Branscomb (2003) argue that even before they reach the valley, university technologies must swim through a 'Darwinian sea' fraught with the clashing cultures of university technologists and business people, scientists with divergent motives for conducting research, meagre seed-stage investment funds, and a dearth of the complementary human, material, and organisational assets necessary for commercialisation. In this paper, we argue that a university-developed technology must negotiate the three gaps shown in Figure 1 to reach the commercial marketplace.

Figure 1 Gaps in the commercialisation of university technology



The *technology discovery gap* separates cutting-edge scientific discoveries from the evaluation of their commercial feasibility. Crossing it involves translation of scientific concepts and terminology into natural language, demonstration of proof of concept and development of market-ready prototypes, and exploration of the invention’s intellectual property landscape. Motivating bench scientists to disclose and commercially develop their discoveries presents a challenge for many universities owing to a variety of professional, organisational and cultural factors (Thursby and Thursby, 2002, 2004; Bercovitz and Feldman, 2006).

The *commercialisation gap* lies between a potentially feasible commercial opportunity and a validated business case ready to accept investment. Crossing this gap entails developing a mechanism for creating value, formulating a business model that can capture part of that value, and identifying an addressable target market. These bellwethers of feasibility are rarely available for early stage university technologies, creating a commercialisation gap between inventors and entrepreneurs (Hsu and Bernstein, 1997; Shane, 2002).

Finally, spinning a technology-based start-up out of a university engenders a host of challenges related to venture formation and funding (Lockett et al., 2003). This *venture launch gap* cannot be spanned until ownership of the underlying technology is secured, a credible management team has committed to the launch, and seed funding has been secured. Without all three components in place, professional investors are unlikely to underwrite the venture’s launch.

Although the literature on university entrepreneurship has expanded rapidly in recent years (Rothaermel et al., 2007), most scholars conceptualise the commercialisation of inventions as a series of transactions between a university and a commercial firm (Bercovitz and Feldman, 2006). Researchers have detailed the hurdles that stand in the way of public-private partnerships (Tuunainen, 2005; Rasmussen et al., 2006), but they have typically modelled intra-organisational dynamics of university technology commercialisation as a black box (Bercovitz and Feldman, 2006). We explore these dynamics by chronicling the development of a programme focusing on early-stage

university technology commercialisation. We identify conflicts that surfaced between basic research, discovery, and commercialisation, and describe intra-organisational partnerships developed to address these conflicts.

This case study presents a narrative account of the origins, evolution, and structure of the technology entrepreneurship program (TEP) developed at the University of Oregon (UO). This programme creates multidisciplinary educational experiences by immersing students from the university's business, law, and science graduate programmes in authentic technology commercialisation processes. We relate how TEP came into being, report on the proponents' encounters with the gaps shown in Figure 1, and describe their responses to the gaps. Our aim is to identify heuristics that may guide other universities seeking to establish technology commercialisation programmes. We include our missteps and recoveries in the hope that others can learn vicariously and avoid our mistakes.

This paper's first author was a partner in the informal coalition that established TEP. In writing the case, we drew upon naturalistic observations, semi-structured interviews with key participants, programme documents, press releases, and grant applications. We describe the inception and evolution of the UO's technology commercialisation programme in the order in which it unfolded. This was a stochastic process, influenced by the actions and decisions of many individuals and organisations and by serendipitous events. Our case begins with the commercialisation gap, the first to be addressed by the UO's programme, and proceeds to discuss the other two gaps in the order in which they became salient.

2 Confronting the commercialisation gap

2.1 Regional economics, technological innovation, and university research

In the early 1990s, stagnation in Oregon's wood products industry coupled with rapid growth in the high technology sector sparked state tax credit legislation that lured chipmakers such as Intel, LSI Logic, and Hyundai to set up plants in Oregon. These firms took advantage of Oregon's cheap land, plentiful water, educated workforce, and low cost of living. In exchange they brought the state thousands of new jobs and tax revenues. But these new plants were not Oregon companies. They provided jobs and salaries, but were beholden to outside interests and exported profits and talent. Furthermore, they had few ties to Northwest research universities. Oregon's high technology sector was largely dependent on outside influences: no mechanism existed to commercialise locally developed technologies and grow them in the regional economy.

Like their counterparts all across the US, proponents of economic development in the Northwest called upon Oregon's research universities to catalyse technology-based manufacturing clusters modelled after California's Silicon Valley, Massachusetts' Route 128, and North Carolina's Research Triangle Park. Social scientists had coined the term 'entrepreneurial university' (Etzkowitz, 1983) to describe the new role of the research university in technology commercialisation, and empirical reports of this new approach were appearing in academic journals (Mian, 1996, 1997; Geuna, 1998; Powell and Owen-Smith, 1998; Mowrey et al., 1999; Siegel et al., 2003).

However, efforts to foment university entrepreneurship in Oregon confronted significant barriers. Oregon's major institutions are geographically dispersed: the state's capital, commercial centre, premier engineering school, and leading business school are

each located in a different metropolitan area, separated by 40 miles or more. University-based technology transfer offices had been established only recently. Thus, the fundamental challenges of technology commercialisation were compounded by additional challenges of evangelising, aligning, and coordinating efforts across spatially dispersed public and private institutions. This case study chronicles the UO's efforts to surmount these challenges.

2.2 Inception of the UO's TEP

An impromptu breakfast meeting in November of 2001 laid the foundation for a partnership between the UO's business school and the Pacific Northwest National Laboratory (PNNL). The director of the UO's Lundquist Center for Entrepreneurship and the director of commercialisation at PNNL hatched a plan to allow MBA students to investigate the market potential of technologies invented by PNNL scientists. Several days later, the director of the UO law school's Center for Law and Entrepreneurship joined the new TEP to bring law students' expertise in patenting and intellectual property into the mix.

From its inception, TEP's mission focused upon catalysing and accelerating the formation of new technology-based businesses. At the heart of the collaboration, however, lay a commitment by each TEP partner to provide graduate students with live-fire experiences in evaluating, planning, structuring, and financing the launch of high-technology start-ups. Importantly, technology commercialisation provided a vehicle to pursue interdisciplinary education, rather than serving as the programme's *raison d'être*. The TEP programme director put it like this:

"The priority is educating students, whether they wind up starting up a business based on TEP or start-up something completely different, working as an entrepreneur, intrapreneur, or corporate employee. We recruit students with the promise to teach them a process for commercializing an innovation, and just as importantly, how to sell their ideas in an effective and compelling way."

Five months after conception, the scheme that had been scratched out on a napkin took form as a summer fellowship programme that mobilised UO graduate students in business and law to assess the commercial viability of PNNL technologies. Two interdisciplinary teams were formed in the summer of 2002, presented with promising technologies, and assigned business and law faculty mentors. Financial stipends for the graduate student participants were tied directly to achieving four predetermined milestones, each requiring written and oral deliverables. The new TEP Fellows visited PNNL's laboratories where they met with the inventors and PNNL's commercialisation staff. PhD students and postdoctoral researchers from the physics and biology departments were recruited to serve as science advisors to the business and law student teams.

When the teams presented their conclusions and recommendations at summer's end, the results exceeded everyone's expectations. Students spoke effusively about the insights they had achieved through their interdisciplinary work. When the fall academic term began, one team enrolled *en masse* in the UO's business planning course to pursue their project, and eventually went on to compete in university business plan competitions. The value students received is captured in the following testimonial from an MBA student:

“I am *amazed* by what I have learned in the last three months. First, I feel like I took an advanced seminar in nanotechnology. My professor was the major-league scientist who invented our technology – and I had a PhD student in chemistry as my personal tutor. Second, I learned a whopping amount about intellectual property and patenting from my law-school team mate. But what really amazes me is this – by the time I finally got a chemist to understand marketing and a lawyer to understand accounting, I realised I’d learned more about business than I did in the whole first year of my MBA.”

2.3 Growing the partnership and extending the educational experience

Flushed with the first year’s success, the TEP partners reviewed and refined the pilot effort, began planning the programme’s second year, and solicited the support of other units on campus. The Vice President for Research offered up seed funding, the deans of the business and law schools provided additional financial support, and the director of the campus office of technology transfer agreed to provide UO technologies for consideration, supplementing PNNL scientists’ technologies with others invented by UO faculty.

The products of TEP’s summer feasibility assessments had been successfully ported into the business planning course that was already being offered in the MBA entrepreneurship curriculum. However, the written business plans that emerged from this course proved far too preliminary for serious consideration by professional investors. So in TEP’s second year, faculty extended the runway by designing the ‘venture launch pathway’, a six-month period of intense mentoring by faculty; exposure to tough, often brutal feedback provided by angel investors, venture capitalists, and other service providers to the entrepreneurial community; and business plan competitions where student teams received more hard questions and candid feedback. Mentors from the business and investment communities joined UO business and law faculty in helping the teams revamp their written plans; venture capital firms and intellectual property attorneys appraised and critiqued their investor presentations.

2.4 TEP structure

TEP was institutionalised in 2003 in the form of a memorandum of understanding expressing the partners’ firm commitment to the programme, and reaffirming the programme’s focus on interdisciplinary education. The programme was offered again in 2004 and 2005, with incremental refinements and modest growth. By the end of its fifth year, the TEP programme had stabilised around a set of tested organisational routines. The programme cycle began each spring with solicitation of applications from first-year MBA students, second-year law students and graduate students in biology, physics and chemistry. As summarised in Table 1, the programme unfolds in six phases, with the first four occurring in the spring and summer and the final two in the subsequent academic year.

Table 1 TEP programme cycle

<i>TEP phase</i>	<i>Summer activities</i>
1 Technology evaluation and selection May 1–30	<ul style="list-style-type: none"> • PNNL and UO Tech Transfer present to new Fellows and Science Advisors a set of high-potential proprietary technologies for their consideration. • Fellows travel to the PNNL facility, and confer with scientist inventors and technology commercialisation managers. Similar visits are held with UO scientists in their labs. • Each TEP team winnows the potential technologies, and selects the technology that they believe holds the greatest promise for commercialisation.
2 Technology discovery June 1–30	<ul style="list-style-type: none"> • TEP teams conduct technology diligence, guided by scientist inventors, technology transfer professionals, and faculty advisors. Teams explore the following issues: <ul style="list-style-type: none"> • technology description • differentiating features • boundaries of application • patents filed/issued
3 Market assessment July 1–30	<ul style="list-style-type: none"> • TEP teams conduct market diligence, guided by faculty advisors with expertise in technology commercialisation, and industry mentors with expertise in new product and business development. Teams explore the following issues and present in-depth oral and written reports: <ul style="list-style-type: none"> • array of potential applications • customer needs analysis • market segmentation analysis • product form, fit, and function
4 Feasibility assessment August 1–31	<ul style="list-style-type: none"> • TEP teams conduct industry analyses, select most attractive market segments, and assess overall commercial feasibility. • TEP teams formally present in-depth written and oral assessments of their technology’s potential for commercialisation to their business, law, and science faculty; UO deans; PNNL executives; regional venture capitalists; and economic development agencies.
<i>Academic year activities</i>	
5 New venture planning Sept. 15–Dec. 15	<ul style="list-style-type: none"> • During fall term, TEP teams convinced that their technology presents an attractive commercial opportunity enrol in LCB’s graduate business planning course, and spend the term building a professional business plan for launching a new venture, and preparing a presentation to investors. • In December, TEP teams present their business plans at Venture Quest, the LCB’s internal business plan competition.

Table 1 TEP programme cycle (continued)

<i>TEP phase</i>	<i>Academic year activities</i>
6 Venture launch pathway January 1–June 15	<ul style="list-style-type: none"> • Teams enrol in workshop seminars, where working closely with mentors with start-up and business development experience, they refine and extend their business plans and prepare them for presentation to investors. • Teams visit angel investors and IP law firms, make investor presentations, receive critiques and advice. • Teams present plans at major international business plan competitions, with travel expenses paid by the Lundquist Center for Entrepreneurship.

3 Confronting the technology discovery gap

3.1 Finding markets for embryonic technologies

TEP had been designed to close the ‘commercialisation gap’ shown in Figure 1. However, many student teams floundered at the beginning, had trouble achieving the programme’s milestones on schedule, and hit their stride only near the end of the summer. TEP faculty concluded that the ‘technology discovery gap’ was a major stumbling block. Jensen and Thursby (2001) point out that many university-developed technologies are so embryonic that they are doomed to remain in the lab unless incentives induce ongoing collaboration between the inventors and the entrepreneurs seeking to take them to market. Many of TEP’s student participants reported that *technology discovery* had been the most difficult and time-consuming phase in the process. Despite the tutelage of their doctoral student science advisors, MBAs and law students reported that programme milestones had forced them to plunge ahead into industry and market analysis before they fully understood the functional mechanisms, advantages, and limitations of their technologies.

Upon achieving demonstration in principle in the lab, few scientists are eager to plow forward to develop a fully functioning prototype. Many promising TEP technologies were very early in their development, compounding the difficulty of technology discovery. Even entrepreneurially inclined faculty inventors often could not fathom the business and legal issues involved in technology commercialisation. Some of the technologies offered up by PNNL had reached a more mature developmental stage than those from the academic labs. But even here, difficulties in comprehending scientific language and business jargon opened up a gap between new-to-the-world technologies and serious business ideas ready for evaluation as investment opportunities. The director of the TEP programme provided the following illustration of the technology discovery gap:

“In the summer of 2004, one of the more exciting technologies presented during Phase 1 was a chemical ‘crab’ that could negotiate multiple liquid media, seek out toxic metals, latch onto them, and safely destroy them. However, this entire process was based on a scientist’s theoretical assumptions about how this would work. He had not demonstrated the capturing mechanism on the bench. He offered compelling arguments about how it should be possible

to capture multiple metals in multiple media. His reasoning was logical and convincing to other scientists.”

“But he had never actually made it work. The teams were faced with spending the next 13 months developing a venture around theoretical musings, not a proven technology. So every one of our TEP teams headed off in another direction. What was most frustrating was that a number of our participants initially ranked this technology highest for innovativeness and potential. But in the last analysis, none of our teams were willing to bet their time on unproven ideas.”

3.2 Narrowing the technology discovery gap

Discussions about the technology discovery gap with the partners at PNNL and UO technology transfer staff led TEP’s leaders to rethink the processes they used to assemble menus of technologies presented to students for selection. TEP staff began asking OTT and PNNL to nominate potential technologies earlier in the cycle, providing time for the vetting of the technologies by TEP staff with input from early-stage investors and technology commercialisation experts. This vetting winnowed prospective technologies, eliminating those that were simply too early in their development. TEP leaders encouraged OTT to cast a wider net, reaching beyond the biology, physics, and chemistry departments to include inventions and innovations emerging from more applied disciplines such as education and computer science.

TEP leaders conferred with the UO Vice President for Research, who was beginning experimentation with ‘translational research grants’ to fund proof of concept research by faculty inventors who expressed interest in commercialising their embryonic technologies. Finally, having observed that science PhD students’ involvement in TEP was more limited than hoped, TEP leaders moved to expand their role from that of consultant/advisor to full team membership. Increasing their involvement entailed discussions with the PhD students’ faculty advisors, some of whom embraced the traditional norms of ‘open science’ that value publications rather than patents (Bercovitz and Feldman, 2005), and maintained that their protégées’ summers should be devoted to bench work in the lab rather than commercialisation projects with business and law professionals. Nevertheless, federal funding for basic research was declining, the level of corporate sponsored research was growing, and many younger scientists were more comfortable with the technology transfer model (Bercovitz and Feldman, 2008). Summer stipends and personal advocacy provided by the VP Research were helpful in overcoming faculty resistance.

4 Confronting the venture launch gap

4.1 New ventures launched by TEP

Beginning in 2004, the TEP programme moved beyond evaluating technologies’ market potential to catalysing the formation of new ventures. The programme began to spin out technology start-ups at the rate of about one per year. Each of these start-ups launched under the leadership of members of the business and law student teams who had initially selected and evaluated the technologies and developed the business plans for their

commercialisation. Three of the four businesses are ongoing, and two of the three have negotiated a license and secured the ongoing involvement of their technology's inventor in the role of advisor or chief technology officer.

- CleanSmart, founded in 2004 upon a patented PNNL technology for reverse micelles in supercritical carbon dioxide, discovered an application for removing highly toxic chromated copper arsenate from pressure-treated wood that has been taken out of service. After graduating, two members of the TEP team incorporated CleanSmart as a C-Corp and began negotiating a sub-license for the technology. Unfortunately, the firm holding the license suddenly lost interest in pursuing the technology and abandoned their licensing contract, bringing CleanSmart's development to a halt.
- Perpetua Power Source Technologies, Inc., founded upon a patented PNNL technology for harvesting thermoelectric ambient energy, is developing ultra-long-lasting energy sources to power wireless sensors. Perpetua launched in 2005, secured seed funding, and negotiated an exclusive license to the PNNL technology. A graduate of the Oregon MBA programme has led the company since its inception in TEP. Perpetua now has assembled a seasoned management team and successfully completed two rounds of venture funding.
- Floragenex was founded in 2006 upon a patented UO technology for rapid detection of genetic factors that are directly linked to the characteristics of mature plants. This information can be used to breed plants with superior characteristics in far less time than is possible with current breeding methods. Floragenex is headed by the MBA graduate who guided the firm through the TEP programme. The faculty biologist who invented the technology joined Floragenex as Chief Technology Officer. The start-up has licensed its technology from the UO, secured its first beta customer and project, and was recently awarded a venture launch grant by the Oregon University Venture Fund.
- TakeShape developed a business plan in 2008 around a PNNL technology that creates three-dimensional images of the human body safely and non-invasively. Three members the TEP student team who wrote the plan have gone on to pursue a venture launch after graduation. The TakeShape team intends to change how athletes set goals and track their progress. For college and professional sports teams, TakeShape promises a revolutionary new way to evaluate talent. For health clubs, the team offers a total workout solution to help clubs attract and retain members. As of October 2008, TakeShape had secured commitments to over \$500,000 in seed funding and was in the final stage of securing a license from PNNL for exclusive use of the technology in the athletic and fitness markets.

4.2 Negotiating licenses and building management teams

Perpetua and Floragenex both made it across what we call the 'venture launch gap' (see Figure 1). Perpetua's founder spent over two years tenaciously pitching to prospective investors and cobbling together a strong management team before he was able to finalise license negotiations and secure his venture capital funding. This time and energy could have been better invested in developing the business. "It was worse than 'Catch-22'," Perpetua's founder said. "I needed seed funding, IP, and a credible team. But whenever I went out looking for any one of these things, I was told to come back after I'd nailed

down the other two.” Floragenex’s CEO found it less challenging to secure his start-up’s intellectual property, perhaps because he was negotiating with a licensing professional who was a close associate of one of TEP’s co-sponsors in the UO Office of Technology Transfer. Even so, the young CEO had to mortgage his home to launch the business, and he must now divide his time between pursuing the beta project that will demonstrate the technology’s viability and soliciting additional funds to support that project.

The venture launch gap swallowed up other aspiring new ventures. CleanSmart was stopped in its tracks at the technology licensing stage. Eventually, team members had to pursue other employment options to service their student loans, bringing CleanSmart’s development to a halt. The jury is still out on TakeShape. The venture launch gap did not take the TEP staff by surprise, but crossing it proved considerably more difficult than anticipated.

4.3 Grappling with conflicting goals

When TEP began to spin out technology ventures, the latent tension between TEP’s dual focus on educating students and commercialising technologies rose to the surface. The programme’s educational model immersed teams in an experiential setting that replicated, formalised, and accelerated the organic technology commercialisation process. The programme’s effectiveness arose from its authenticity, and TEP’s first spinouts injected realism and energy. But as teams’ rising expectations were dashed by the venture launch gap, their disappointment began to jeopardise the TEP programme’s reputation.

By the conclusion of the 15-month programme, many students had learned their technology, packaged it in a professional business plan, assimilated the critical commentary of their TEP mentors, pitched the concept to no-nonsense professional investors, and presented the case at several university-sponsored business plan competitions. At each stage, they had taken criticism and staved off pot-shots; after each presentation, they had picked up the pieces of their plan and gone home to reassemble them into a sturdier configuration. During this process, teams bonded tightly and came to identify closely with ‘their’ technology and its business plan. After learning so much and working so long, students became convinced that they had earned the right to carry the project forward. Often, the TEP faculty concurred. However, the programme’s director reframed the problem posed by the venture launch gap in this way:

“We need to remember that over 90% of our students will not start-up an entrepreneurial business right after graduation, and while we need to have some start-ups, they are not the primary focus of our efforts ... My sense is that many programs similar to ours started out with education as the central goal (as we did), but through mission creep, educational goals gave way to trying to maximize revenue, deals, IP licenses, business competition prizes, and other metrics. If we want to avoid pitfalls that have diverted other programs, we must never lose sight of the importance of delivering value to all of our students.”

Having reaffirmed experiential education as their fundamental objective, TEP programme leaders re-engaged the problems posed by the venture launch gap. As Perpetua’s founder pointed out, TEP teams on the launch pad faced three challenges – licensing the technology, securing seed funding, and building a strong and credible management team. Although, TEP’s sponsors in PNNL and OTT recognised and applauded the student teams’ accomplishments, their licensing professionals had reservations about consigning valuable intellectual property to students with limited industry experience. Unlike most of

the students, PNNL and OTT knew that along the path to commercialisation lay professional investors who would shy away from funding a team lacking seasoned managers with experience in launching start-up ventures. TEP's programme director provided an example:

“One of our first teams, AquaEssence, worked with a technology from PNNL based on self-assembling monolayers on mesoporous supports. The monolayers contained molecules immobilised on a scaffold that could absorb arsenic molecules from drinking water. This was a great team that identified an attractive market.”

“However, when it came time to negotiate a license and raise funding, PNNL balked, and the team fell apart. Some of its members received attractive job offers, and they weren't willing or able to risk job security for the uncertain world of entrepreneurship. Several of the team members were close to going the venture launch route, but in the end none of them took the leap. The TEP programme was left with a great technology and a viable business plan, but no one to execute.”

In short, despite significant accomplishments and impressive performance in business plan competitions, many TEP graduates discovered that pursuing their new venture was impossible, and opted to accept job offers from corporations or law firms. Even those who persevered and launched their ventures struggled to secure seed funding and negotiate licenses for the technology. TEP faculty had invested substantial human and financial resources in training and mentoring TEP students. Students had forsaken other academic and personal goals while they transformed embryonic technologies into credible investment opportunities. Nevertheless, the usual result was a defunct venture – delivering no economic benefits to the inventor or the student entrepreneurs.

5 Programme evaluation: taking stock of TEP

As the 2005 programme cycled to a close, TEP staff conducted an in-depth examination of the programme's accomplishments, shortfalls, and future prospects.

5.1 Interdisciplinary education

TEP had exceeded the founders' expectations in terms of creating a rich learning environment. The evaluators agreed that the programme had assumed a major role in the experiential education of MBAs, law students, and to lesser extent science graduate students. TEP participants had experienced the challenges of multidisciplinary teamwork, used and integrated the tools of legal and business professionals, and understood the process of bringing a scientific discovery to market. Students found their employment opportunities enhanced, and highly qualified new applicants were being attracted to the UO's graduate programmes solely by the prospect of being selected to participate in TEP. Working in interdisciplinary TEP teams provided a real-world experience afforded by no other academic programme at the university.

5.2 Accelerating technology transfer

Mapping the TEP programme onto our three-gap model (Figure 1), TEP had made significant strides toward closing the *commercialisation gap*. Results of the programme's efforts to span the *technology discovery gap*, however, were mixed. At UO, TEP teams lacked access to engineering or medical school researchers, whose discoveries are often focused on real-world problems. Instead, teams typically worked with technologies that focused on basic science. TEP students continued to struggle with the challenge of transforming curiosity-driven discoveries of academic scientists into commercial products.

TEP's technology transfer partners offered a more positive assessment. PNNL reported that the students' analyses had uncovered unforeseen and promising applications for their technologies, and characterised their work as more valuable than similar assessments received when they'd engaged professional business development consultants. Moreover, the benefits were not limited to cases in which the student team had concluded that their technology offered a viable commercial opportunity. In other cases – after investigating industry structure, competitive rivalry, other emerging technologies, customer needs, and the intellectual property landscape – teams had recommended *against* commercialisation. PNNL's commercialisation manager reported that they found such 'negative results' every bit as valuable as positive results. The university's Director of Technology Transfer offered a complementary viewpoint:

“Information that exposes limitations, concerns or non-existent markets is really useful to our innovators, who may have little experience in assessing these factors. TEP teams' negative findings have pointed innovators in a slightly different direction that put them on a fast track toward improvement. Or it may be that the basic research is 15 years ahead of its time – simply no infrastructure or uptake is possible through a commercial channel. Our office doesn't have the bandwidth to prospect for opportunities across the entire IP portfolio. TEP creates a halo of students, educators, mentors, and experts who look deeply into the crystal ball, and that's hugely valuable.”

Yet despite TEP's progress in narrowing the technology discovery and commercialisation gaps, the programme had made little progress in addressing the venture launch gap. Transforming students into credible founding CEOs lay beyond TEP's capabilities, and Oregon's nascent ecosystem contained relatively few technology entrepreneurs with start-up experience who could be recruited to pilot TEP spin-outs.

5.3 Sustainability and scalability

The 2005 programme evaluation concluded that TEP had yet to achieve a stable and sustainable position. As the programme entered its fifth year, TEP continued to enjoy enthusiastic support of the founding partners, who hailed the programme's educational value and its success in developing technology commercialisation options. The programme's reputation was attracting a growing pool of capable and motivated applicants. Nevertheless, it was apparent that financial support from the campus administration and the business and law school deans could not continue to grow indefinitely, making it necessary to develop external funding sources.

Programme expansion was another requirement for stability. By relying on bootstrapping, donated faculty time and the uncompensated assistance of members of the

business and investing communities, TEP had grown to serve four student teams each year. As its reputation spread, more students sought to participate, but programme resources and faculty members' bandwidth were already stretched beyond their capacity. Furthermore, the 'deal flow' drawn from UO and PNNL's IP portfolios was reaching its limit to support an expanded programme. Thus, although, TEP had developed an innovative model for entrepreneurial education, the programme's continued survival depended on developing a new business model.

6 Serendipity: a path to financial sustainability

Knowledge-based economic development has been conceptualised as unfolding through a series of sequential transactions (Bercovitz and Feldman, 2006). The transactional mechanisms these authors cite are sponsored research support, agreements to license university intellectual property, private-sector employment of students, and the formation of new start-up firms. To supplement these formal transactions, Bercovitz and Feldman add to the list an informal mechanism that they call *serendipity*, an unexpected confluence of need and solution.

6.1 Oregon legislature creates university venture fund

Although investment in transferring university technology has grown in recent years, many institutions measure performance in terms of royalties from technology licenses but continue to "resist the notion that a research university should be concerned about state economic development" [Tornatzky, (2001), p.272]. Research findings suggest that technology transfer offices' performance in "areas contributing to regional economic development (such as in-state licenses and licenses to start-ups) has not improved at the same pace" as metrics based on invention disclosures, licenses, and royalties [Waugaman and Tornatzky, (2001), p.3].

In 2005, the Oregon State Legislature reinforced the role of the state's public universities as engines of regional economic development by passing an innovative bill providing an unprecedented tax incentive (60% state income tax credits) to corporate and individual donors who chose to support commercialisation of promising university discoveries and campus-based entrepreneurship education. The bill created the University Venture Fund (UVF). This legislation does not simply offer tax deductions, but grants dollar-for-dollar credits against state tax liabilities, creating an unusually compelling incentive for donors. In addition, donors can claim Federal tax deductions for their full contribution (UO Venture Development Fund, 2009).

More importantly, the Oregon law was written to create an 'evergreen' revenue source: When a university realises financial returns from UVF-funded investments in technology commercialisation, the university repays the tax-credit contributions to the state treasury. Upon repayment of these 'old' tax credits, 'new' tax credits are generated automatically. Since state tax credits equal 60% of donors' gifts, every dollar that is paid back gives the university the opportunity to bring in an additional \$1.67 in tax-incentivised contributions. This novel financial arrangement offers a pay-as-you go path to building a permanent endowment.

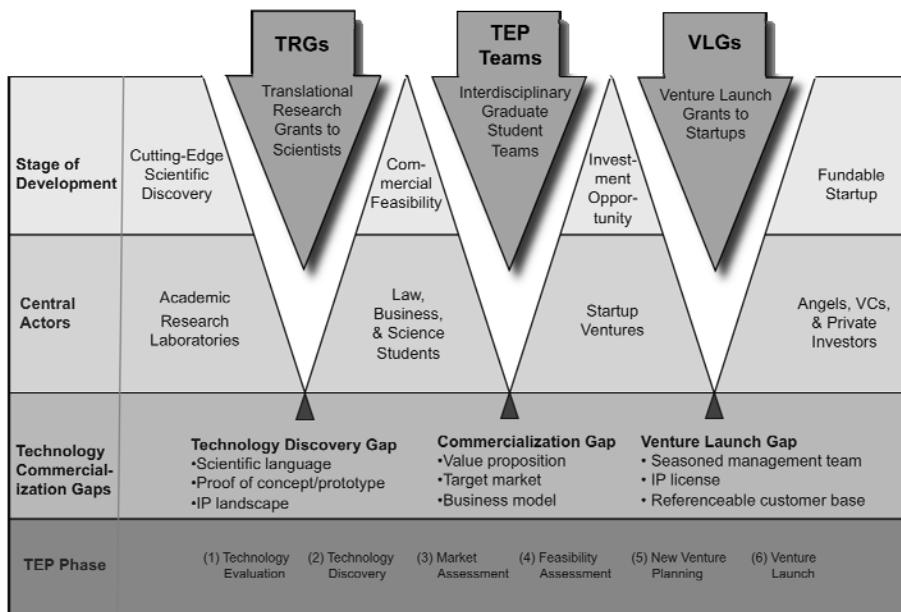
6.2 Toward an entrepreneurial university

UO’s TEP, as noted above, had met its core educational objectives and catalysed a handful of spinouts, but had failed to develop a sustainable business model. However, the programme was well positioned to seize the opportunity presented by the University Development Fund. Over its first five years, TEP had accumulated valuable organisational resources, including:

- 1 educational credibility and legitimacy within academic and administrative units across campus
- 2 a social network populated by programme mentors and advisors who occupied influential positions in the region’s business and investing communities
- 3 a set of fine-tuned organisational routines for mobilising, incentivising, and training graduate students to evaluate a technology’s latent value
- 4 an academic business-planning curriculum that could turn embryonic scientific discoveries into investment opportunities
- 5 a working partnership linking the programme’s champions through bonds of trust, cordial relations, and shared values.

These resources and capabilities prompted UO’s top administrators to select the TEP as the centre piece of the university’s strategy for raising and deploying venture fund donations. TEP was assimilated into a newly created entity, the ‘innovation and entrepreneurship programme’, and an umbrella initiative established to move the UO toward the ideal of an ‘entrepreneurial university’ (Etzkowitz et al., 2000). In 2007, the National Science Foundation’s Partnerships for Innovation Program awarded UO a grant to build out the programme’s infrastructure. The Oregon Nanoscience and Microtechnology Institute, a state-funded signature research centre, supported the new initiative by awarding a matching grant.

Figure 2 Innovation and entrepreneurship initiative fills the gaps



The new innovation and entrepreneurship initiative's core premise is that transferring scientific knowledge from the university to the private sector can promote regional economic development (Lockett and Wright, 2005). The large arrows at the top of Figure 2 (labelled TRGs, TEP Teams, and VLGs) show how the new programme's design deploys three components designed to narrow the technology discovery, commercialisation, and venture launch gaps that proponents encountered during the programme's inception and expansion. The panel at the bottom of the figure maps the six phases of the TEP programme (detailed in Table 1) onto the UO's Innovation and Entrepreneurship initiative.

6.2.1 Technology discovery gap

To narrow the technology discovery gap, the UO has set up a programme to award competitive translational research grants to academic inventors who commit to pursuing proof of concept and prototyping projects to move their technologies closer to market. These awards are restricted to researchers who have submitted an invention disclosure, and who agree to actively assist a TEP student team should their technology be selected for analysis. To infuse market considerations, the selection of translational grant recipients is informed by an external advisory board made up of professionals from Oregon's high technology manufacturing and venture capital investing communities. The first round of grants was awarded in 2008.

6.2.2 Commercialisation gap

To close the commercialisation gap, the UO has set out to double the number of students participating in the TEP programme and increase the programme's multidisciplinary reach. PhD students from the sciences (who participated as consultants in earlier years) are now serving as full team members alongside business and law students. Engineering students from UO's sister institution, Oregon State University, are being recruited for the 2009 programme cycle. To increase the pool of technologies available for these new students' commercialisation analyses, Oregon State's technology transfer office has proffered intellectual property from their own portfolio for potential adoption by TEP teams.

6.2.3 Venture launch gap

To address the venture launch gap, the UO has set up a programme awarding competitive venture launch grants (VLGs) to accelerate the development of young companies spun out to commercialise technologies licensed from the UO. Funds are provided to promising start-ups emerging from TEP or other on-campus sources in the form of grants, without provision of equity or warrants. Private sector advisory board members with corporate and professional credentials bring market-related considerations to bear on the selection process. Criteria used in selecting venture launch grant recipients include:

- 1 strategic importance of funding to the start-up's development
- 2 identification of an external source of investment funds that is likely to be secured by VLG seed funding
- 3 the technology's potential for disruption within the market segment identified

- 4 market analysis that confirms projected demand
- 5 evidence that the company will be able to execute
- 6 prospects for significant financial returns from the license.

Perpetua and Floragenex, the ventures that launched from the TEP programme in 2005 and 2006, are among the start-ups funded in the early rounds of venture launch grant awards.

7 Overcoming contradictions: pitfalls and lessons

Beginning the transformation of a venerable research university into an entrepreneurial university entails grafting a technology commercialisation mission onto the traditional academic missions of education and scientific discovery. Pursuing this new mission means shepherding scientific inventions across the technology discovery, commercialisation, and venture launch gaps. To do this, fundamental contradictions between learning, discovery, and commercialisation must be confronted. The creation and evolution of the UO's TEP provides guidance on how these contradictions may be overcome. The following heuristics have emerged from our analysis:

- 1 Taking a new scientific discovery to market may feel like crossing a valley of death, but our experience at the UO shows that the crossing may be easier if the valley is broken up into a series of three more tractable gaps: the technology discovery gap, the commercialisation gap, and the venture launch gap.
- 2 Genuine commitment to interdisciplinary and experiential graduate education can assuage the tension between a university's academic and commercial missions. Framing Oregon's programme as a vehicle for collaborative learning rather than for wealth creation conferred legitimacy and overcame potential opponents' resistance. Monitoring and improving learning hinged upon developing metrics that systematically tracked educational outcomes and benefits to students and other stakeholders.
- 3 Graduate students are valuable human resources. Oregon's experience shows that when their work is structured by a well-designed programme and timed by periodic milestones, collaborative learning can generate invaluable insights. When skilful practitioners are added as mentors, the students learn to distinguish bona fide insights from wild ideas.
- 4 Building multi-disciplinary teams is essential. We found that students from professional schools need scientists to explain technologies and translate jargon. Technologists need business experts to explain the importance of customers and cash flows. Engaging lawyers early in evaluations of commercial feasibility avoids journeys down blind alleys.
- 5 Authenticity is essential. Our experience at Oregon suggests that only by replicating the organic technology commercialisation process can educational and commercial objectives be achieved simultaneously. Technologies offered to students for evaluation must have genuine promise, mentors must have experience in live-fire

settings, and investors must evaluate the team's business plan exactly as they would any other investment opportunity. Otherwise, the experiential learning opportunity devolves into a contrived academic exercise.

- 6 Negative findings are positive outcomes. Oregon's track record indicates that fewer than one out of five teams will ultimately attempt to form a business. One implication is that it is extremely important to set reasonable expectations, and to align the expectations of all participating groups. Fortunately, students learn as much from failure as from success, and university technology transfer offices benefit directly when inopportune excursions into the market are identified early and aborted.
- 7 University technology transfer succeeds not by royalty income alone. Particularly in universities like Oregon that are not situated near an R&D-intensive industry cluster, technology transfer offices can catalyse regional economic development best by enabling start-ups and licensing to start-ups.
- 8 Beware of mission creep. The UO began its commercialisation programme to cultivate experiential education and spark entrepreneurial activity on campus. Pursuing these goals was possible only in collaboration with the business and investment communities, and these collaborations injected market forces and pressures for regional economic development that threatened to compromise the programme's original focus. Only by insuring that interdisciplinary education remained the programme's 'true north' could the programme's integrity and credibility be preserved. Whenever conflict arose between education and pursuing financial returns, education took precedence.

We hope others find these observations instructive. However, the most fundamental lesson we take away from our analysis of Oregon's commercialisation programme concerns the collaborative processes its proponents developed, not the content and structure of the programme they devised. The TEP programme director put it like this:

"My central premise is that our program is exemplary in that it combines extraordinary interdisciplinary education with a collaborative approach to regional economic development. I'm not sure how different that makes us, but it certainly is the key to our success."

This collaboration drew together academic scientists, professional school faculty, university administrators, and technology transfer professionals. It was fuelled by a mixture of naiveté and perseverance, as implied in this reflection by the entrepreneurship centre's director:

"You know, right from the start TEP operated on an 'ignorance is bliss' basis. As a group, we did not follow the best practice of benchmarking and modelling TEP on other programs. Instead, we plunged ahead, took a problem-oriented approach, and invented collaborative solutions that would keep us moving forward together. This meant checking your ego at the door, and leaving turf issues on the back burner. Right from the start, all of us seemed to understand that the only way this thing would work was to keep all the partners on board and to hold each other to true partnership behaviour."

The UO's new Innovation and Entrepreneurship Program has institutionalised the foundational TEP programme without altering the programme's focus on interdisciplinary education. It draws upon hard-won lessons about technology

commercialisation learned throughout the TEP programme's development. Now, thanks to the serendipitous enactment of Oregon's tax-credit-funded University Venture Fund, the UO has fashioned a business model that has the potential to achieve long-term financial self-sufficiency.

We contend that these achievements were possible only because the TEP programme developed organically and maintained its unwavering commitment to providing rich and unique educational experiences for graduate students. Consider an alternative scenario: imagine that a financial windfall had allowed the UO to undertake an ambitious programme of regional economic development with the Innovation and Entrepreneurship Program's scope and objectives, but without prior firsthand experience in building the TEP. Assume that the charge was to spin out university technologies to form regionally-based start-ups, but that this project had been undertaken without TEP's stockpile of tacit and codified knowledge, educational credibility, reputational capital, and social relationships. We suspect that this effort would have been less likely to survive and succeed than the artless, grass-roots approach to university entrepreneurship described in this paper.

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