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The University is the Classroom: Teaching and Learning Technology

Commercialization at a Technological University

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Abstract

In 2013, the University of Strathclyde became the first Scottish university to receive the prestigious THES UK entrepreneurial university of the year award. In this article, I describe how successful technology commercialization education in this leading UK-based technological university is deeply dependent on the state of the university's entrepreneurial ecosystem. Two case studies illustrate the relatively minor "supporting" role that conventional teaching plays in the practice of technology commercialization, and the major role that a comprehensive university entrepreneurial ecosystem can play. Lessons drawn from teaching and learning technology commercialization at the University of Strathclyde are discussed. These include "teaching by stealth" through the ecosystem, basing students' class assignments on their own technology, and the use of local role models in class. I conclude by summarizing today's challenges and opportunities facing Strathclyde's entrepreneurial ecosystem.

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1. Introduction

In 1756, a young instrument maker tried to set up shop in Glasgow, Scotland, but ran into trouble with the local metalworkers' Guild because he had not been apprenticed for seven years. Fortunately, he had good contacts with several Professors in the University of Glasgow, who had been his first customers; indeed, one of them had been a mentor of his and had arranged his 'fast-track' training in London. They let him set up shop inside the University grounds and gave him the title of "Mathematical Instrument Maker to the University" (O'Brien 2002). This could be the first recorded case of a university business incubator in history.

In 1763, a Professor of Natural History asked the instrument maker to fix a scale model of the Newcomen steam engine, which kept stalling (O'Brien 2002). The instrument maker, as many readers will have realized by now, was James Watt, and the professor who set Watt on a journey that would power the Industrial Revolution was John Anderson, the founder of the university where I now work.

Two years of experimentation later, and stimulated intellectually by numerous conversations with leading academics and bright students including Adam Smith, Joseph Black (who discovered carbon dioxide and developed the concept of latent heat) and his successor to the chair of chemistry John Robison, James Watt made a conceptual breakthrough (Carnegie 1905). Many years later, he recalled that it happened during a Sunday afternoon walk in May 1765 through Glasgow Green, just south of the University on the banks of the river Clyde (Hart 1859).

Watt took eleven lean and hard years to commercialize his radical improvement on the Newcomen engine. The university's entrepreneurial ecosystem helped again and again during this time. It introduced him to a business angel, John Roebuck, who funded prototypes

and enabled Watt to patent the invention in return for two-thirds of the profit. When Watt and his investor ran out of money, the university helped him survive by investing in a canal scheme he promoted (O'Brien 2002).

Watt's access to the University's networks spurred his progress in technology commercialization in many different ways over a considerable length of time. Watt gained access initially through family connections; he was never a student and was too busy making a living to attend lectures. But University professors acted as teachers, customers, facilities providers, knowledge providers, mentors, investors, connectors to other investors and last but not least, friends (Muirhead 1858). In return they received skilled service, but something more: the connection with a curious yet practical brain that complemented the more abstract minds of the professoriate. Watt's rooms were regularly full of students and staff (Muirhead 1858, pp.62-63). Clearly, they got some value out of the interaction. Today, we would call this "knowledge exchange".

I think there is an important lesson here for teachers "of" (as opposed to "about") technology commercialization: people learn how to commercialize technology in many ways, and attending class is only one way. For some members of the university community, as I explain later, attending technology commercialization class may actually trigger "anti-learning" (Argyris 1993) behaviors. The focus of this article is therefore not on *teaching* technology commercialization. It is on how a university's entrepreneurial ecosystem, including regular teaching provision, can enable the university community to *learn* technology commercialization – even those who think they know it all already. If, today, James Watt was a technician in the University of Strathclyde and trying to start his own instrument-making business, he would probably not attend a regular technology commercialization class at the Hunter Centre for Entrepreneurship, even though he would be eligible to participate in one.

But he could definitely learn from and contribute to the ecosystem that Hunter Centre staff, along with many other system actors, have helped to construct.

In the next section, I summarize the evolution of the University of Strathclyde's entrepreneurial ecosystem and provide an example of how the ecosystem enables learning how to commercialize technology. I then discuss the Hunter Centre for Entrepreneurship's contribution in teaching technology commercialization. Finally I conclude with success factors in technology commercialization education and training at Strathclyde and the challenges and opportunities that it faces in educating, in the broadest sense, technologists in entrepreneurship.

2. The University of Strathclyde

John Anderson is not just remembered as the person who set James Watt on his steam-driven journey of technology commercialization. He was a radical educationalist who clashed with the University of Glasgow bureaucracy over his desire to invite artisans to attend his lectures, and had the last word in this debate by leaving money in his will to found “a place of useful learning” for anyone, regardless of background¹. Two hundred years later, his institution, the University of Strathclyde, is an international technological university that also has one of the top ten business schools in the UK and hosts the only Fraunhofer Institute (Europe's largest application-oriented research organization) outside Germany². It featured as one of the five case studies in Burton Clark's book “Creating Entrepreneurial Universities” and in a follow-up book five years later (Clark 1998; 2004). It is based a stone's throw from Watt's original university incubator space, in the center of Glasgow in the West of Scotland, a region that relied on heavy industry from the Industrial Revolution until rapid de-industrialization in the 1980's.

¹ <http://www.universitystory.gla.ac.uk/biography/?id=WH0179&type=P> accessed 25 July 2013

² <http://www.strath.ac.uk/about/universityoftheyear/> accessed 25 July 2013

Strathclyde received the Times Higher Education UK University of the Year award in 2012. In 2013, it became the first Scottish university to receive the Times Higher Education UK entrepreneurial university of the year award. The award was made in recognition of the outstanding culture of entrepreneurship fostered at the University through education, research, mentoring and partnership programs.

The University of Strathclyde was independently ranked 5th in the UK for spin-out and start-up companies formed in the ten years to 2012 (Harris 2013). It has formed over 50 spin-out companies, of which around 40 are still trading in some form, making sales of approximately \$120m per annum and employing around 700 people³. It also remains in the all-time top 10 in the UK for cumulative license royalty income, mainly thanks to the drugs Tracrium® (GSK plc) and Isovorin® (Pfizer) which were developed by Strathclyde scientists. The university's Hunter Centre for Entrepreneurship, created in 2000 with a £5 million (\$7.5 million) endowment from alumnus Sir Tom Hunter, is engaged at many levels in teaching technology commercialization. More importantly, the Hunter Centre has worked with other academic and service departments to create an entrepreneurship ecosystem which enables Strathclyders to learn how to commercialize technology.

3. The evolution of Strathclyde's entrepreneurial ecosystem

Table 1 plots the introduction of new elements of the entrepreneurial ecosystem at Strathclyde from 1984, the year that spinout activity was first formally recognized and encouraged by the University. This timeline was derived from internal documents, staff interviews and archived newsletters. At the time, the Greater Glasgow area was undergoing rapid deindustrialization under the Conservative Government. Recognizing its potential role in reindustrializing the region for a new era, the University of Strathclyde became a pioneer

³ <http://www.strath.ac.uk/businessorganisations/licensingspin-outs/spin-outcompanies/> accessed 25 July 2013

in encouraging university spinouts. It opened one of the UK's first university business incubators in 1990 and on the instructions of the then principal (president) of the University, Professor Sir John Arbuthnott, a teaching unit called Strathclyde Entrepreneurship Initiative was formed in 1996 to deliver entrepreneurship education to students across the university. In this unit's elective modules, students from all faculties and years engaged in experiential learning together. The unit's Director reported directly to the Deputy Principal and had an advisory board drawn from each of the university's five faculties. This unit's work was recognized by Sir Tom Hunter, and following his endowment in 2000, it became the Hunter Centre for Entrepreneurship. It has since expanded greatly and become a recognized leader in entrepreneurship education, research and knowledge exchange. However, within Strathclyde, the Hunter Centre is one of many actors that are building the university's entrepreneurial ecosystem together. The university now offers a wide range of services for entrepreneurs funded from a mix of internal, public and private sources.

Like the funding history of the Hunter Centre, small scale internally-funded initiatives to build the entrepreneurial ecosystem have been expanded with long term, non-repayable stakeholder or "quasi-equity" funding from alumni and finance houses and limited life "grant" funding from regional, national and EU government agency programs. As grants end, the University reverts to in-house funding of services at sustainable (sometimes lower) levels, supplemented by voluntary work of students and alumni.

A good example of this funding pattern is professional services to entrepreneurial students and young alumni, such as advice and networking events. This began with informal mentoring by staff in the Strathclyde Entrepreneurship Initiative. Then one student commercialization advisor post was created in 2000, funded by a UK government competitive award which was won by Strathclyde as part of a consortium of five Scottish universities. The post incumbent won several large EU grants to expand his activities and

employ additional staff. With the ending of these grants, the university now funds a more limited number of posts internally, but has developed programs of engagement with students and alumni volunteers that leverage the work of this smaller core of staff, enabling an impressive range of services to be maintained.

New activities have continually been piloted over the past two decades, as shown in Table 1. Some have been inspired by initiatives elsewhere, such as London Business School's Enterprise 100 or Stanford's Stanford Entrepreneurship Network. Others were in-house ideas, such as Strathclyde's Celebration of Entrepreneurship Day and the Strathclyde Students into Business small discretionary grant scheme.

Prior to 2008, Strathclyde's entrepreneurial ecosystem actors cooperated with each other, but there was no central coordinating body. An important development occurred in 2008 when responsibility for several major knowledge exchange programs was formally transferred from the Hunter Centre to professional services departments in 2008, following a university review of the Hunter Centre's activities and its change in status to an academic department of Strathclyde Business School, with greater emphasis on research excellence. This was the first step in a more coordinated approach to Strathclyde's entrepreneurial ecosystem.

In 2011, the loosely connected and disparate set of "bottom-up" enterprise groups and activities, which we used to call the Strathclyde Entrepreneurial Community of Practice, was brought together by Professor Tim Bedford, the Associate Deputy Principal for Knowledge Exchange and Research Enhancement (the university's senior officer responsible for Knowledge Exchange). He started regular "Enterprise Forum" meetings enabling updating of engaged individuals and departments across the university and brought a more informed approach to the coordination of Strathclyde's entrepreneurial ecosystem.

3.1 Current activities

Table 2 shows the range of current activities designed to maintain Strathclyde's entrepreneurial ecosystem, and the leading and supporting organizations in each activity. Currently, the university provides an integrated service of "soft" to "hard" start-up support activities for staff, students and alumni entrepreneurs. These range from for-credit entrepreneurship education at one end through training, mentoring and networking activities, to small grant schemes, significant equity investment funds, and in-house incubation facilities. They are delivered by a variety of service and academic departments, often working together to deliver activities. The main service departments are: Research and Knowledge Exchange Services or RKES (the Technology Transfer Office), Alumni and Development, and the Careers Service. The main academic department is the Hunter Centre for Entrepreneurship in the Strathclyde Business School, but other departments also provide specialized teaching. For example an MSc in Environmental Entrepreneurship is run from the David Livingstone Center for Sustainability in the Department of Civil Engineering. A wide range of student enterprise activities are run independently by student enterprise societies and are also supervised by the Hunter Centre, RKES and a Scotland-wide organization called the Scottish Institute for Enterprise (SIE).

In January 2013, the Strathclyde Entrepreneurial Network (SEN) brand was chosen as the umbrella brand for enterprise activities at Strathclyde. Inspired by the Stanford Entrepreneurship Network model at Stanford University, SEN brings together all Strathclyde activities relating to entrepreneurship, innovation & creativity-related activities generated by professional services and academic staff (including research, teaching, executive education, knowledge exchange, consultancy, and support for enterprise) under one umbrella. The Hunter Centre's Head of Department is a member of the SEN steering group, alongside representatives of professional services departments. A sophisticated on-line central touch

point to all enterprise and entrepreneurship activities at Strathclyde has been created, and a physical on-campus 'Enterprise Hub' in a central location easily accessible by students, staff, alumni and visitors, with meeting and hot-desk facilities and advisors on-hand was launched in October 2013 during the University's Celebration of Enterprise Day.

SEN currently has four activity areas: Nurturing Entrepreneurial Talent, Supporting New Ventures, Celebrating Success and Influencing Policy and Practice. These areas make sense if one thinks of entrepreneurship as a process that is affected by context (Bosma and Levie 2009). It starts with individuals spotting an opportunity or thinking about starting a business, then trying to start, then starting and perhaps growing and succeeding. The first three activity areas help the entrepreneurial process along, while the last one focuses more on context. If I were to criticize the SEN framework, it would be that it focuses more on start-ups than growth potential. The balance is shifting however, with new initiatives in funding, skills for growth and role models.

Arguably, with these recent changes in the management of Strathclyde's entrepreneurial ecosystem, we have moved into a third phase: integration. Actors within SEN will be able to integrate learning from research, education and outreach activities to provide better services and increase activity rates and the quality of entrepreneurship within the ecosystem.

A good example of collaborative effort in entrepreneurship ecosystem building by multiple academic and service departments is Strathclyde 100 (S100; described below), which was launched in 2003 and recently celebrated its 10th anniversary. S100 has made a critical difference to many emerging technology spinouts at Strathclyde since its founding, and demonstrates how a broad approach of enabling learning opportunities generates value far beyond that which classroom-based "teaching" technology commercialization could do alone.

3.2 Strathclyde 100

S100 is an exclusive invitation-only network of successful alumni and friends of the university, which meets 3 or 4 times a year to listen to students, staff and alumni pitch their new businesses and to give feedback and advice. S100 is led by RKES and supported by the Alumni and Development Office and Hunter Centre staff. The management board of S100 is chaired by the principal (i.e. president or vice-chancellor) of the University. Currently, 43 S100 members serve as voluntary Enterprise Partners to mentor other Strathclyde early-stage entrepreneurs in their own time. There is a strong sense of trust and altruism between alumni of the university. Many S100 members have invested in or joined the board of ventures that presented at S100. We have even had experienced S100 members pitch their own latest ventures at meetings. Mentors are carefully matched with entrepreneurs and the relationships are monitored by the enterprise advisor, having regard for conflicts of interest and personality.

The inspiration for S100 was a similar initiative at London Business School, my previous employer. As the then Director of the Hunter Centre, I arranged for Peter Kelly, who organized the founding year of Enterprise 100 at London Business School, to give a talk at Strathclyde. This inspired the then Director of Alumni Affairs and Development, Adrienne Hall, to lead the creation of a similar organization at Strathclyde. We found that the subscription-only investors' club model did not fly with our alumni and raised regulatory issues, so S100 became more of an exclusive philanthropic network that enabled successful alumni to help early-stage entrepreneurs get going, but with the added attraction of occasional high quality guest speakers on topics of particular interest to the members and networking with like-minded successful entrepreneurs. More recently, there has been less emphasis on guest speakers and more emphasis on pitches by budding entrepreneurs and engaging members of S100 as Enterprise Fellows with specific mentoring roles. Selected MBA

students are specially trained by HC and RKES staff to help early stage entrepreneurs to hone their seven minute pitches for the S100 meetings. Pitches are less about funding and more about strategic issues, often around finding key people, strategic partners or customers.

S100 fits into a segmented enterprise offering for alumni. Younger or less experienced alumni are served by the SEN enterprise team, while the invitation-only S100 is an exclusive circle of successful and experienced alumni and friends of the university. The Enterprise Partners scheme connects experienced alumni who are willing to act as mentors with less experienced alumni. Younger alumni regularly pitch to S100 meetings but are pre-screened and coached to pitch professionally. Pitching to S100 is seen as an honor. Both groups also meet at events like the biennial Enterprise Awards Dinner.

Two brief cases of technology commercialization may serve as examples of how the Strathclyde entrepreneurial ecosystem works to enable academics, students and others to learn how to commercialize technology. Teaching played a minor “supporting role” in both cases, but it is likely that neither business would have taken off as it did if the ecosystem had not been in place to bring actors and resources together.

3.3 Cascade Technologies

Erwan Normand, a Physics PhD Student who recognized the commercial potential of the Quantum Cascade Laser (QCL) technology he was working on, enrolled in an evening technology entrepreneurship class at the Hunter Centre in 2000. The assignments he did for this class revealed the scale of potential markets for this platform technology. Indeed, the sheer breadth of potential markets that Erwan revealed in his class presentation presented a classic dilemma for entrepreneurs commercializing platform technologies: which market should he focus on first? Mentored by the student enterprise advisor over the next year, he was able to jointly file a patent with the university in 2002 on a QCL based electronic

“sniffer” platform he developed with his PhD supervisors, and in 2003, while still a student, he became the first participant in the Upstarts Program developed by Strathclyde University Incubator (SUI) and CTO of the University’s first technology-based student-led spinout. As part of the program, SUI located experienced alumni to form a core team for the emerging business, Cascade Technologies.

In 2004, Erwan and his colleagues, Strathclyde alumnus Richard Cooper Commercial Director) and Iain Howieson (R&D Director) presented at the first ever Strathclyde 100 event. Several S100 members subsequently invested in the business. Over the next eight years they raised £6 million in venture capital. They secured their first multi-million pound order in 2008. In 2011 they broke into the detection of leaks in gas canisters on rapid production lines with a sale to Unilever. In 2012, Cascade Technologies made its first £1 million profit on £6 million revenues and broke into the Sunday Times TechTrack100. It employs 51 people and is the world’s most advanced designer, developer and manufacturer of Quantum Cascade Laser gas analyzers.

3.4 Nautricity

In the early 2000s, Cameron Johnstone, a senior lecturer in the Department of Mechanical Engineering’s Energy Systems Research Unit (ESRU) and an expert in renewable energy systems, realized that pioneers in the tidal energy industry were marinizing wind energy turbines. He anticipated that they would face insurmountable problems of cost and, working with academic colleagues in the ESRU, began to design appropriate second-generation equipment from relevant theoretical principles. Several years of testing a novel free-floating contra-rotating dissimilar rotor turbine design with scale models followed, funded from 2004 to 2007 by a Scottish Enterprise Proof of Concept scheme and thereafter with small awards from SEN and the University’s Commercial Development Fund. After working with RKES

on global patent applications, Cameron pitched at a S100 “sustainable technology” event in February 2009. His main “ask” was for industrial partners to help build a full scale 10 meter version, rather than help with starting his own business with this technology.

A former MBA student of mine, Dave Pratt, was in the audience that evening. Dave had been spending the previous 18 months reviewing renewable energy proposals as a venture capitalist and the title of the event drew him in. After the event, he remarked:

“I thought Cameron was great and I was impressed by how far he had taken the device and by how he had maximized the value of the funding received from Scottish Enterprise’s Proof of Concept Program. It’s clear to me that the device is ready and working.”

Dave and Cameron agreed to start a business together, and the university funded Dave’s due diligence under its Technology Talent Initiative (now called the Executive Director Designate Program). As a serial technology entrepreneur who specialized in commercialization of university IP with several IPOs to his credit, Dave knew exactly what to do to road-test the technology, scope the market and develop a strategic plan and viable business model:

“I thought I might help a little bit to move it forward. The first thing I did was help them get their strategy absolutely clear. Cameron had three or four different ideas so we sat down and worked through which of these options was the best one.

“The next challenge is to build it on a scale that’s big enough to be commercial and then get a track record for generating electricity reliably. At that stage, we may look into building really big tidal farms.”

He quickly raised venture capital from an Aberdeen-based “super-angel”. The spinout was formally started in 2010 with a global license for the technology from the University, and the prototyping phase was stepped up. Cameron learned so much about technology

commercialization and technology entrepreneurship from working with Dave during this period that he took over the role of CEO, leaving Dave some free time to develop other new ventures but remain a director of the company. At the time of writing, a full-scale, pre-commercial CoRMaT 500kW tidal turbine is under test in the Scottish Government's Marine Energy Test station in Orkney. Nautricity's business plan has been accelerated following a large government grant and the securing of a seabed lease off the Scottish coast. First power from the site is targeted for 2015. Cameron now regularly "gives back" to the ecosystem by, for example, inspiring PhD students in Hunter Centre technology commercialization classes.

4. Hunter Centre for Entrepreneurship: a leading entrepreneurial ecosystem partner

Pittaway and Hannon (2008) advocate two models of institutional strategies for developing enterprise education in universities: single department-led models and campus-wide models. At first sight, it would appear that the Strathclyde model is a single department-led model, with the high-profile Hunter Centre at its heart. This would be a disservice to many other departments such as RKES, the Alumni and Development Office, the Careers Office, and many academic departments that nurture the university's entrepreneurial ecosystem. Indeed, I would argue that universities need strategies for developing entrepreneurial ecosystems more than they need a strategy for enterprise education (cf. Katz 2003). Developing enterprise education without consideration of the surrounding ecosystem is like sowing seeds without regard for the nature of the seedbed.

Balancing the roles of academic and professional services departments in this ecosystem is not easy, but some lessons can be drawn from the Strathclyde experience. Strathclyde's current model is neither single department nor campus-wide, but more of a solar system, with a number of planets (academic and professional services departments) of different size and

power orbiting the sun (the university's senior management and their strategic plan for the university). To keep this solar system working, and stop collisions, the planets need heat, light, and a gravitational field to keep them moving in the right direction.

In my view, interest from the very top (the sun, if you will) is good for morale but, on top of that, intervention at critical junctures is necessary to “realign the planets”. For example, the intervention of the university's principal in setting up the Strathclyde Entrepreneurship Initiative, with a non-traditional approach to university education, was a critical catalyst. As initiatives proliferated and the ecosystem became complex, boundaries of responsibility had to be rewritten – again, this had to be done by senior officers making difficult decisions to bring clarity to the ecosystem. An example would be transfer of responsibility of much knowledge exchange activity within the ecosystem undertaken by the Hunter Centre to professional services departments in 2008, and a directive to the Hunter Centre to focus more on excellence in research. In the next phase, as departments pursued their defined areas of responsibility, a senior officer had to intervene to ensure departments coordinated with each other and aligned themselves with the university's strategic plan (through the formation of the Enterprise Forum). Finally, the current integration phase under the Strathclyde Entrepreneurial Network brand requires careful oversight to ensure that potential synergies from coordinating the different expertise of different departments are realized. An example would be integrating learning from research into training and advice programs. The SEN steering group is key here.

The Hunter Centre is currently a major contributor to the entrepreneurial ecosystem (which we now call SEN) rather than its natural hub. Many of the activities that are carried out by Entrepreneurship Centers in other universities, and that used to take up a significant amount of Hunter Centre staff time, are now run by professional services departments, such as RKES and Alumni and Development. Examples include one on one advice to prospective

entrepreneurs and entrepreneurship events management. As a “regular” academic department, the Hunter Centre is much more sustainable under this model because of its growing research and dedicated education program income. Service or elective teaching is a precarious way to make a living in universities. With dedicated research and education programs, however, the Hunter Centre is capable of more significant growth and impact, both externally in terms of policy impact and internally in terms of its effect on the university than a conventional service-based Entrepreneurship Center. It can still initiate innovations within the ecosystem, and if they look like being successful, they can be spun out into professional services departments.

Most of the Hunter Centre’s teaching is now on the Business Enterprise pathway of the BA Business degree and in both core and elective teaching on the Strathclyde MBA in ten locations around the world. However, as an Entrepreneurship Center within a technology university, the Hunter Centre has naturally attracted staff and PhD students with an interest in technology commercialization, and it is active in classroom-based teaching of technology commercialization at bachelors, masters, doctorate and executive education levels, including for-credit and not-for-credit courses and practical workshops for staff, students and alumni and for external organizations.

Table 3 summarizes the main class-based offerings which emphasized or enabled technology commercialization in the 2012/2013 academic year. Many other classes involved some element of technology commercialization, for example through student projects or consulting assignments with technology-based ventures. The following section offers some general lessons learned from over fifteen years of teaching technology commercialization at Strathclyde.

5. Lessons learned from educating technologists on how to commercialize technology

For an Entrepreneurship Center based in a business school, teaching technology commercialization to staff in other faculties (i.e. schools) such as science or engineering raises tricky issues (Barr et al. 2009; Wright et al. 2009). First, staff and students in other faculties may have very mixed feelings about business in general. Second, most people – and especially academics who are not entrepreneurship faculty – think that entrepreneurship can't be taught. Third, there is the issue of compensation: business schools tend to value the time of their staff at a higher rate than other faculties. This causes financing dilemmas for cross-faculty service teaching given scarce faculty teaching time.

At Strathclyde, some of these tensions have been managed through the use of RKES as an intermediary organization for continuing professional development CPD courses for staff. Some of these courses are taught in whole or in part by Hunter Centre faculty while others are contracted out to external training providers.

Another solution is split Masters level courses where the host department runs a seminar series with invited entrepreneurs from their sector, and the Hunter Centre provides a generic entrepreneurship course (such as its New Venture Creation class) for students from a range of Masters courses at the same time in a block course of two to three days. This generates economies of scale for the Hunter Centre but still provides the relevant context, industry contacts and up-to-the-minute industry news that are most valued by students.

A third solution is to train senior students such as MBAs to coach entrepreneurial staff or students. Strangely, some faculty seem more willing to listen to business students than to business faculty!

Finally, I have observed that many senior academics display an “anti-learning” pattern (Argyris 1993) when it comes to classroom-based teaching of technology commercialization. By this I mean that they can find being put into the status of “student” to be threatening and discomforting, especially if there are “real” students in the class, and if they know no more about the subject than those “real” students, but feel, as professors, that they should know. Typically, they last no more than two of these classroom sessions before exiting the class.

For senior academics, I have found that ‘teaching by stealth’ works better. This is much more subtle than action-based courses, which is another approach to this issue (e.g. Rasmussen and Sørheim 2006). The idea is to induce reflective, double-loop learning (Argyris 2002) by providing opportunities for learning that do not threaten the self-perceptions of senior academics by making them revert to the status of students. This can include informal advice coupled with formal approval of stages in technology commercialization, training of junior team members to get a “trickle up” effect, facilitating the development of links with experienced “professional” start-up CEOs, co-opting them to help with training programs for others, and giving them access to high level business contacts only if they accept coaching in pitching their business.

Recent research reported by one of my PhD students (Costa and Levie 2012; Costa 2013) suggests that hiring commercially experienced managers shortens the time to discovery of viable business models in emerging university spinouts. It also enables excellent academic researchers and teachers to continue to make new discoveries that might form the basis of further spinouts, and teach the next generation who may go on to commercialize those discoveries. While there are exceptions, on the whole there is little to be gained from encouraging senior academics who lead labs to become mediocre entrepreneurs. This is probably the main lesson from Strathclyde’s pioneering experience in promoting university spinouts. As an illustration, when I joined the University’s Business Ventures Group (the

oversight committee of Court for the university's investments in spinout companies) in 2003, the combined losses of ventures in the portfolio exceeded combined revenues. Thanks to much greater use of "professional" CEOs, many of whom are alumni, the picture today is very different. Several businesses have been turned around by these professional CEOs, who typically brought a market focus to the company for the first time. Eight of the 40 active spinouts have been acquired, generating returns to the university, and some Strathclyde spinout entrepreneurs are doing it all over again with new companies.

For more junior staff, postdocs and late stage PhDs, short technology commercialization courses can be inspiring. In my experience, the key is that the participants can use a technology they are working on themselves as the vehicle for application of business theory.

Critical elements of a course would include:

- IP awareness: what you own and what you can share; your interests and the university's interests
- Understanding the potential a technology – and "rival" technologies – have for generating definable new product/service features
- Understanding the potential in a market, i.e. significant benefits to customers that can be provided by definable product/service features – through interviewing real potential customers and/or market experts
- Business Model Generation
- Storytelling: the pitch

The value of these elements can be transmitted through plenty of examples and role models. It is one thing to hear about technology roadmaps for the first time. It is another to develop one for your own technology. But it is only when you hear from a serial entrepreneur that technology roadmaps are routinely used in large technology companies to track young

technology companies, and that he or she uses them regularly, that you realize that technology roadmaps are *useful*.

6. Conclusion

Technology commercialization fits the University of Strathclyde's sense of itself as "the place of useful learning". It is encouraged because it contributes to the university's "third mission" of knowledge exchange and supports the careers of faculty, students and alumni. At Strathclyde, commercialization activities including patenting, licensed IP and spinout activity resulting from research have been included in career advancement assessment systems for some time. They are now also included in performance agreements by the University with the Scottish Government, and in the UK-wide assessment of research excellence (Research Excellence Framework) through measures of research impact.

The entrepreneurship ecosystem that enables technology commercialization at Strathclyde relies on cooperation and coordination between service and academic departments working together on many different projects and on leveraging the goodwill and energy of students, staff and alumni. Teaching activities at the Hunter Centre form just one strand of this ecosystem; on their own, they would have little impact. In the development of this ecosystem, there was encouragement of innovation from below rather than central planning. For example, Strathclyde100, Strathclyde Students Into Business, the original Strathclyde Entrepreneurial Network project, Celebration of Entrepreneurship Day, Supercoaching the Entrepreneur, Enterprise Matters, the Enterprise Awards Dinner, Strathclyde Academy of Distinguished Entrepreneurs were all initiatives of individuals in academic or professional services departments, but implemented by teams across departments. Strathclyde has a clear vision and strategy of how to become a leading technological university. In ensuring that a thriving entrepreneurial ecosystem appropriate to this vision is sustained, and does not get

mired by complexity, senior officers play a vital coordinating and integrating role. But there is still a sense of, as our current principal puts it, “don’t wait for me to give permission”.

As an early entrant to enterprise activities with a wide set of start-up services, Strathclyde faces the challenge of staying fresh with its enterprise offerings, and of presenting an integrated service to students, staff and alumni. Another challenge is the sustainability of support after pump-priming funds are exhausted. It is meeting these challenges through the SEN Steering Group and the wider Enterprise Forum, unified branding (i.e. SEN), and leveraging the energy of students and alumni.

Our latest challenge will be to make the most of the new \$150 million Technology and Innovation Center now being built on campus, to create much stronger ties between established and emerging technology-based businesses and the University. The Center will focus on advancing science from low to high technology readiness levels through collaborative research with multiple industry partners. It will have specialist, shared and flexible laboratory facilities where world-class researchers respond to real problems in partnership with industry, government agencies and other organizations, and significant conference facilities. Current major collaborative industry projects are focused on Energy, Future Cities, Health, and Manufacturing sectors. It is likely that as a result of this new development, the Hunter Centre, and indeed Strathclyde’s entrepreneurial ecosystem, will focus more on enabling technology commercialization in established businesses, linking emerging and established businesses, and facilitating venture growth.

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Table 1 Evolution of provision of the entrepreneurial ecosystem at the University of Strathclyde, including all initiatives launched

1984	Business Ventures Group created as a committee of the University Court with a remit to encourage and support spin-out companies based on university research.
1990	Strathclyde opens Scotland's first university incubator (Strathclyde University Incubator: SUI) with equal funding from the university, an enterprise agency, a bank and a venture capital house.
1996	Strathclyde Entrepreneurship Initiative (SEI) opens with internal funding from the Principal's Office to provide entrepreneurship electives available for all students. A wide range of funding sources were subsequently tapped to grow the unit, ranging from a neighboring university (in return for teaching provision), regional and city enterprise agencies, ERDF, and a private educational trust. A major boost to the initiative came in 2000 with a £5 million endowment from Sir Tom Hunter, alumnus, entrepreneur and philanthropist to grow SEI into a world-class "Hunter Centre for Entrepreneurship".
1998	Dedicated university spinout company development officer post created in Technology Transfer Office. Like the incubator, this happened much earlier than in most UK universities.
1999	Technology Entrepreneurship for Postgraduates training program starts at SEI, funded by Strathclyde and Glasgow Universities; Strathclyde with University of Glasgow wins £3.3million for professionally managed seed capital fund ("Synergy Fund" for pre-venture capital technology commercialization activity from UK Government University Challenge Fund (jointly funded with a Trust and a charitable foundation).

2000	<p>SEI renamed Hunter Centre for Entrepreneurship in 2000 following a £5 million endowment from Sir Tom Hunter, alumnus, entrepreneur and philanthropist; First “entrepreneur-in-residence”.</p> <p>Business Plan Competition launched, managed by entrepreneur-in-residence with £40,000 prize money from an enterprise agency and a bank. Strathclyde with 4 other Scottish universities wins funding for the Scottish Institute for Enterprise” from UK Government “Science Enterprise Challenge” Fund; enables hiring of student business advisor.</p>
2001	<p>Supercoach® Entrepreneurial Training “train the trainers” course runs at Hunter Centre for first time.</p>
2002	<p>As open business plan competitions proliferate, Strathclyde business plan prize money diverted to a “Strathclyde Students Into Business Program” with quick grants to fund market research and intellectual property protection – the better to win other business plan competitions! Scottish Enterprise and Royal Society of Edinburgh launch Enterprise Fellowships Program. Strathclyde wins more applications than any other university – a good example of leveraging external resources. Annual day-long “Celebration of Entrepreneurship” launched with inspirational events for students, staff, alumni and local people, joint venture of two academic departments with Careers Office.</p>
2003	<p>Strathclyde 100 launched: exclusive invitation only network of successful alumni and friends of the university, meet 3 or 4 times a year to listen and give feedback to new businesses started by students, staff and alumni; led by Alumni and Development Office, supported by Hunter Centre and Tech Transfer Office (TTO). S100 members volunteer to mentor specific early-stage entrepreneurs in own time (3</p>

	years later formalized as Enterprise Partners programme). Some S100 members later invest in showcased businesses.
2004	Strathclyde Entrepreneurial Network launched for entrepreneurial students and young alumni – a series of networking events run by TTO staff and a student champion funded by Scottish Institute for Enterprise; SUI launches “Upstarts” program to link inexperienced technical startup entrepreneurs with experienced alumni to strengthen their management teams.; Technology Talent Initiative (now Executive Directors Designate Programme) launched; this project funds chief executive officers designate in re-revenue, pre-launch spinouts. Financed by ERDF and city enterprise agency.
2005	£950,000 SEEKIT funding (Scottish Government and ERDF) secured by TTO to grow services to young alumni entrepreneurs (advisors, events, networking) for 3 years, funding renewed for further 3 years in 2008
2006	Enterprise Matters Newsletter launched, funded by SEEKIT (published regularly until 2011).
2007	Four-year undergraduate Business Enterprise pathway launched by Hunter Centre in the BA Business degree; Strathclyde Enterprise Awards Dinner launched with first of biennial Enterprise Challenge awards; Strathclyde Innovation Fund launched; first S100 London meeting.
2008	Strathclyde Innovation Fund closes first round (£4.5 million) of fundraising for spinouts with Braveheart, a Scottish venture capital company.
2011	Strathclyde Academy of Distinguished Entrepreneurs (a Hall of Fame) launched; Enterprise Forum monthly administration meetings under chairmanship of senior officer meets monthly to coordinate enterprise activities across the University; 3-day intensive Enterprise Academy launched for Strathclyde’s early-career researchers;

	<p>Vertically-Integrated Project “Building Strathclyde’s Enterprise Community”: Student-led activities for students interested in entrepreneurship, support the small enterprise support team in TTO, student leaders get credit, participants get official recognition for participation in enterprise skills-building activities. Internally-funded enterprise advisor appointed. This replaces the previous externally-funded posts.</p>
2012	<p>SUI launches Gabriel Investments, a business angel syndicate to channel start-up funds to high quality start-ups. University Court approves new commercially-driven approach to spinout creation. RKES creates independently chaired Commercialization & Investment Advisory Board to oversee strategic developments and recommend individual investments.</p>
2013	<p>Strathclyde 100 launched in Dubai campus</p> <p>Strathclyde Enterprise Pathway launched with separate pathways for students and researchers.</p> <p>Strathclyde Entrepreneurial Network refreshed as a collaborative network that brings together the University's academic and professional services to support enterprise and commercialization activity at the University.</p> <p>Strathclyde Business School Business Clinic launched: Third year business undergraduates consulting microbusinesses in Glasgow</p> <p>Times Higher Education UK Entrepreneurial University of the Year award</p>

Table 2. Who does what in the Strathclyde Entrepreneurial Ecosystem (as of December 2013)

	Hunter Centre	Research and Consultancy Services	Alumni and Development Office	Careers Office	Strathclyde University Incubator	Others	Senior Officer
COORDINATION AND INTEGRATION							
Strathclyde Entrepreneurial Network Steering Group	Support	Support	Support				Lead
Enterprise Forum (SEN Operations Group)	Support	Support	Support	Support	Support	Support	Lead
NURTURING TALENT							
Strathclyde Enterprise Pathway	Support	Lead					
BA Business Enterprise	Lead						
Enterprise Vertically Integrated Projects	Lead	Support	Support				
Enactus	Support	Support					
Student Enterprise Society	Support	Support					
For credit entrepreneurship education	Lead					Additional	
Knowledge Exchange & Innovation Training	Support	Lead					
SUPPORTING NEW VENTURES							
Academic Spinout support		Lead					
Student advisor		Lead					
Incubation space (Enterprise Hub, Incubator)		Lead (students)			Lead		
Rising Star programme		Lead			Support		
Business Plan competitions	Support	Lead					
Strathclyde 100		Support	Support				Lead
Strathclyders Into Business		Lead					
Graduate Entrepreneur Visa Scheme	Support	Support		Lead	Support		
Executive Directors Designate Programme		Lead					
Commercialization & Investment Advisory Board		Lead					
Commercialisation Advisory Panels		Lead					

Supercoach® Entrepreneurial Training	Lead	Support					
Gabriel Investments (business angel syndicate)					Lead		
CELEBRATING SUCCESS							
Strathclyde Academy of Distinguished Entrepreneurs		Support	Lead				
Enterprise awards Dinner		Lead	Support				
Celebration of Enterprise Day	Support	Lead	Support	Support		Support	
INFLUENCING POLICY AND PRACTICE							
Entrepreneurship research	Lead					Additional	
Alumni entrepreneurship events	Support	Support	Lead				

Table 2. Technology commercialization courses provided by the Hunter Centre for Entrepreneurship in academic year 2012/2013 (details on specific courses are available at www.strath.ac.uk/huntercentre)

Bachelors level (all faculties)

Knowledge, Science and Technology-based Businesses (1 semester)

New Venture Creation (1 semester)

Masters level (all faculties)

Entrepreneurship, Innovation and Commercialization (1 week block)

New Venture Creation (1 week block)

PhD level (all faculties)

Technology Commercialization and New Business Development (3 full days)

Post-doctoral/Early Career Researcher level (all faculties)

Knowledge Exchange and Innovation Training (3 day residential)

Executive Education for startup entrepreneurs and coaches of entrepreneurs:

Supercoaching the Entrepreneur Workshops (2 weekends)

Informatics Ventures School for Entrepreneurs (5 day residential)