Engineering Innovative Products

A Practical Experience

EDITED BY

Roger Woods • Karen Rafferty • Julian Murphy • Paul Hermon

WILEY

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The authors dedicate this book to the many students who have actively engaged in the company and product creation activities described here.

Contents

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The authors are most grateful to the experts who have helped to develop the course material and who have also contributed individual chapters.

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Foreword

Engineering Innovative Products is more than just a description of the innovation process. The book is based on experience of running an inspirational and popular course which takes students through the process of starting a new company. A number of ventures that have come into existence through the course are described, with the twists and turns of their journey demonstrating the culture required for success.

The topic of innovation has attained much importance with universities and governments in their quest for economic growth and wealth creation. This is because the pace of technological change has accelerated, precipitating further acceleration in the development cycles of products and consequently in the changing shape of industrial sectors. Hence, what were established models of innovation are being replaced by new ones, with even large enterprises having to adapt and change. New opportunities are frequently based on new business models for getting product to market, something a startup company is able to do easily. This is particularly true in sectors where digital technology either makes up the product itself, or is used more generally as a means of marketing and selling it. At the same time, the barriers to starting a new venture have much reduced, not least because of the training, support and incentives offered. New ventures are a prerequisite for a dynamic economy and now is the time when they have an excellent chance of success.

This book takes the reader through all the essential steps in creating a successful business. Practical insights are given about how new product concepts can be identified and prototyped. The role of product engineering and marketing is discussed. What makes a good business plan is described, alongside illustrations of successful elevator pitches to communicate it succinctly. Teamwork and the roles of each team player are presented. At the same time, the role of finance and raising investment capital is described. Sections on marketing, branding and intellectual property are contributed by expert practitioners. Finally, and of most interest to educators, suggestions for exercises and assessments when running a course are presented.

But there is more. The creation of a new venture is a process of discovery as much as of academic study, and the authors demonstrate this through a number of case studies. The benefit of a cluster with inbuilt experience, partners and competitors is made clear. Members of the cluster can mentor and present critical advice from the earliest stages. The need to respond to critical input and be prepared to significantly adapt the venture is shown by example. The role of crisp presentation and description of the most important components of the new venture is emphasized, particularly when seeking investment. Finally, the benefit of a competitive element at all stages – including assessment by an expert panel – completes the excellent formula.

I warmly recommend this book to the reader for both information and inspiration. Educators using it as the basis of a course on business creation will be well served. The individual reader will become familiar with what it takes to be an entrepreneur. The chances of successful innovation in engineering will be much improved. The book is timely because the opportunities for success are there to be grasped.

Andy Hopper
University of Cambridge, UK
24 February 2014

Preface

Innovation is currently a hot topic and is related directly to economic development. The creation of companies resulting from innovative projects and processes is seen as central to the economic development in many countries. Like many governments worldwide, the UK government's main industry division, the Technology Strategy Board, uses the 'innovation' word all over their web pages and highlights that their goal is 'to accelerate economic growth by stimulating and supporting business-led innovation'.

Whilst most university management schools have embraced the concept of company creation and innovation, some engineering schools have still to incorporate product design as a core element in their courses. This is probably because it represents yet another module amongst the increasing number of technical subjects that need to be covered in the degree programme. We would argue that it is now becoming a core topic and, combined with engineering skills, represents a very interesting skill set for engineers to develop.

A number of years ago, the Schools of Electronics, Electrical Engineering and Computer Science and Mechanical and Aerospace Engineering at Queen's University Belfast embarked on separate activities to introduce students to the concept of product design, company creation and commercialization. However, rather than just create a series of talks to introduce the students to the topic, both schools introduced hands-on practical courses which acted to get the students engaged in developing their own product ideas and then building on this work to create a full commercial proposition. The course has matured to such an extent that the students are now getting shortlisted for, and indeed winning, local and national commercialization competitions.

The purpose of this book is to capture the process, and provide examples of best practice and insights into the practical experiences and development that have been undertaken over the past three years. It is based on the material that has been developed in the courses by topic experts external to the university, whom we engaged to interact with the students; topic areas include finance, marketing, branding, presentation and intellectual property. Also, two of the authors have founded their own companies and brought this experience to bear on the enclosed material. For completeness, two of the groups that undertook the course have provided detailed insights into their practical experience of going the full distance and creating their own companies. In addition, the text builds upon the experiences of some 12 business propositions that have been created during this time.

Throughout the book, the authors have relied on their own experiences and student examples to emphasize the points made and illustrate both good and poor approaches. In addition, the text

includes a number of exercises entitled '*Try this*', which stretch the reader to apply directly some of the material covered in the various chapters; this acts to help future students and readers who are engaged directly on the commercial activity.

The activity has been rated highly by external organizations which are involved in linking entrepreneurs to commercial opportunities, such as the Northern Ireland Science Park. The Institution of Engineering and Technology, a professional organization which undertakes evaluation of degree course material (termed accreditation), highlighted the activity as 'exemplar' on their most recent visit. It is hoped that lecturers interested in developing their own courses will find this text invaluable; we also firmly believe that any budding entrepreneur will find valuable lessons contained within this book, as the example business plans developed by the groups have stood up to commercial scrutiny.

List of Abbreviations

API	Application Programming Interface
BIL	Business Innovation Link
BS	British Standard
CAD	Computer-Aided Design
CATS	Credit Accumulation and Transfer Scheme
CEO	Chief Executive Officer
CES	Cambridge Engineering Selector
CFO	Chief Financial Officer
CMO	Chief Marketing Officer
COO	Chief Operating Officer
CTO	Chief Technology Officer
DFMA	Design for Manufacture and Assembly
DIY	Do It Yourself
EN	European Standards
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
FEA	Finite Element Analysis
FMEA	Failure Mode and Effects Analysis
GPS	Global Positioning System
GPU	Graphical Processing Units
IAESTE	International Association for the Exchange of Students for Technical Experience
IET	Institution of Engineering and Technology
IP	Intellectual Property
IPC	International Patent Classification
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
LLP	Limited Liability Partnership
LVCSR	Large Vocabulary Continuous Speech Recognition
MBTI	Myers–Briggs Type Indicator
MIM	Metal Injection Moulding
MVR	Multimedia Voice Recognition
NDA	Non-Disclosure Agreement

NISP	Northern Ireland Science Park
PDS	Product Design Specification
PLC	Public Limited Company
POC	Proof of Concept
PPC	Pay per Click
PSL@Q	Programmable Systems Laboratory at Queen's University
QR	Quick Response
QUB	Queen's University Belfast
QUBIS	Queen's University Belfast Industrial Services
RFID	Radio-Frequency Identification
SEO	Search Engine Optimization
SME	Small to Medium Enterprise
SWOT	Strengths, Weaknesses, Opportunities and Threats
TDI	Technical Development Incentive Scheme
TPMS	Tyre Pressure Monitoring System
TSB	Technology Strategy Board
US	Uniform Resource Locator
US	United States
USP	Unique Selling Point
VAT	Value Added Tax
VIP	Very Important Person
WFST	Weighted Finite State Transducer

1

Introduction

Roger Woods

1.1 Introduction

Over the past 30 years, there has been a shift in the world's economy which has occurred for a number of reasons. Large-volume manufacturing has moved from the West to the East due to much cheaper production costs, largely because of cheaper labour and the optimization of the value chain (Zhu *et al.*, 2006). In addition, economies such as those in Canada and Australia have been buoyed by the availability of natural resources such as the supply of phosphorus and, of course, oil and natural gas. In the absence of these resources, the remainder of the Western economy has looked to rely on the *knowledge-based economy*; one route has been to exploit much of the knowledge that exists in universities and research centres to either undertake technology transfer into industry or to create spin-off companies.

The Bishop William Lawrence University Professor at Harvard Business School, Michael Porter, famously said that 'innovation is the central issue in economic prosperity', a vision to which the West would appear to have been fully committed. For example, the strap line of the UK's Technology Strategy Board (TSB) is *Driving Innovation!* and the recent focus of the UK higher education institutions' upcoming Research Excellence Framework on *Impact of Research* suggests a direct link between research innovation and commercialization. One UK funding agency, namely the Engineering and Physical Sciences Research Council (EPSRC), now has a clear message on 'fueling growth and prosperity' on their main web page; a clear indication that the work funded in universities should have an impact on the economy.

This approach is being adopted more widely. For example, the EU's Horizon 2020 programme is described as the financial instrument implementing what they call an *Innovation Union*, a Europe 2020 flagship initiative. It is described as 'securing Europe's global competitiveness' and sets the agenda for involvement of small to medium enterprises (SMEs) in EU research.

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All of these factors send a clear message to universities about commercializing research, either through the development of spin-off companies which look to directly commercialize the output of university research, or other approaches such as spin-in activity or technology transfer schemes. Indeed, many governments will provide incentives in the form of grants, subsidies and tax breaks to encourage business creation in certain areas of the economy. This has resulted in a clear shift in policy 'to encourage investment and exports as a route to a more balanced economy; and to create a more educated workforce that is the most flexible in Europe' (HMG, 2013). Coming on the back of the economic strife of the past five years, the ability to innovate and bring to market new forms of technology becomes increasingly attractive for many governments.

1.2 Importance of SMEs

It has been recognized that the creation of innovation is directly linked to the commercialization of university research. This can come about either as a result of direct collaboration with large industry in sponsoring university research and then commercializing it, or by undertaking technology transfer by direct partnering with companies with specific expertise. However, the culture also exists to create spin-out companies from research teams wanting to commercialize a specific aspect of their research and for individuals or teams in an external company to get direct access to university technology with the aim of possibly looking to spin into the university.

In any case, many countries now place a high level of importance on the existence and promotion of SMEs. Indeed, it is clear to anyone reading the European Commission's 2011 Factsheet on *SMEs in Horizon 2020* (EC, 2011) that there is an urge to get SMEs involved in EU research and to exploit innovation. The TSB has a clear strategy of innovation (Nicholas *et al*., 2009; TSB, 2012) and we clearly see that SMEs are the life blood of the future economy.

Many universities, such as Stanford University and the University of California at Berkeley, have clearly demonstrated their intention to exploit research for commercialization. In the UK, the University of Cambridge stands out in its capacity to be able to commercialize university research, although the host university of the authors, Queen's University Belfast, has managed to 'punch well above its weight' in terms of spin-out activity.

1.3 Inspiring Innovation for Engineers

In many cases, innovation and the concepts of startups have been seen as the *bread and butter* of management and business school courses. Many of the processes involved – such as financial planning, business development and marketing and sales – are seen as central to what is taught on the courses in these schools. Once the innovative idea or product has been created, the key challenge is to look at the development of the business from this initial concept. This is a skilled step and requires a detailed understanding of marketing sales, product development and the company creation process.

The authors fully acknowledge the importance of the business expert in this process, but this approach has major limitations in the creation of technology-driven SMEs for a number of reasons. With many innovative industries linked closely to technology, the scientific understanding of engineering students puts them in an ideal position to create innovative,

hi-tech businesses. With resources limited, they will have limited scope to employ the business expertise and will have to engage in a do-it-yourself (DIY) approach. Moreover, the marketing of many of the aforementioned investment agencies (e.g., TSB), suggests that commercial support is there to assist the entrepreneur to achieve this exact goal. Therefore, we would argue that there is a strong case to bring the company creation expertise to engineering students, who have the ability to create innovative products. The objective is therefore to determine the best way to educate and invigorate engineering students with the necessary skills to do this.

1.4 Rationale

The question is how to apply this knowledge in engineering and science courses in a highly practical and realistic manner. How do we introduce engineers to the issues of product design and company creation to commercialize this product? This has been the driving force behind a three-year effort in the university which has been highly successful, as evidenced by the numbers of students who have been successful in competitive funding schemes. It was felt that this was a very important activity but had to be carried out in a highly effective and practical manner. There were many examples of business and professional development courses trying to educate students in the business processes, but given that there was no directly practical exposure to company creation in the course, it was clear that a new approach was needed.

A number of methods were developed to meet these challenges and they have been evolved based on staff and student experiences, including the creation of material with a number of innovative aspects. A key feature was to ensure student engagement in the development of a commercial product, along with experience of the processes needed to create a company to commercialize it. This includes the preparation of a full business plan and commercial pitch.

The text outlines the detailed processes involved in creating the business idea, advising students on branding, marketing, sales, finance and intellectual property (IP) issues and developing a feasible commercial demonstrator leaning towards product. It also reflects the experiences of the students who have undertaken this activity by including two chapters from teams who have experienced the courses and who have had a successful output from applying to funding competitions. The development has been identified as *exemplar* by the Institution of Engineering and Technology on a course accreditation visit by its accreditation panels in 2010.

1.5 Focus

Many texts have been created around commercializing technology, using innovation in product design and in the creation of spin-off companies. We would not suggest that this book supersedes these excellent texts, but should be seen as a complementary text aimed at undergraduate and postgraduate engineering and science students involved in commercializing early ideas. The text takes a hands-on approach which allows students to apply all of the processes and then experience the pressures of taking an idea all the way to actual commercial product.

We believe that the focus of this book is very different from any previously published text. It covers how engineers can create and develop innovative products and then allows them to marry effectively the costs, sales and marketing needs of business creation with the practical realizations of creating the product; in particular, it allows them to experience the fine

balance between these competing aspects. The overarching objective is to realize a product which can be created within the realistic timescales of a one-year module and without the need for advanced technology which might involve detailed research; the result is the creation of startup companies involving students which could realistically create revenue from the proposed solution not long beyond the time period of the course.

The book content has come from two highly successful and innovative courses undertaken by final-year engineering students in the Faculty of Engineering and Physical Sciences at Queen's University. The courses provide groups of students with key skills and gives them all of the essential background and insights to allow them to organize themselves into teams (effectively companies), identify a key market need, create a realistic product to address the issue and then develop the full business proposition to create a successful company. Fundamental to the approach is that the resulting products are both technically and commercially viable, as students have been guided along the process by a combination of engineering faculty and experienced external practitioners.

We highlight the processes involved in achieving this and the experiences of both the students undertaking the course and the staff organizing it. The work has been based on the practical experience of several generations of students coming up with business propositions and then creating their own companies. The book also presents the views from the student perspective by including written experiences from previous student teams. In addition to generating the business aspect, the students have to consider all of the engineering aspects in producing a feasibility study which typically includes the generation of a working prototype.

The intention of the book is to capture this process, provide a checklist of best practice and relate to practical experiences and developments that have been undertaken over the past three years. This should provide the basis for both students and staff in universities to create activities in their own engineering faculties, but we believe that a lot of the ideas and information provide a detailed treatise for young entrepreneurs in creating their own companies by highlighting pitfalls and insights, based on real examples.

The material created to support the course is innovative and different in that the students are exploiting their technical knowledge to undertake a genuine product validation in a highly practical manner. The course involves the teams working as a group and associating roles in the form of Chief Executive Officer (CEO), Chief Financial Officer (CFO) and Chief Technical Officer (CTO), etc. with the aim of producing a slick, 15-minute *Dragon's Den*-style pitch, a full business plan to outline the commercial potential of the project and a preliminary concept prototype.

1.6 Processes and Organization of Course

The complete activity is given in the flow diagram of Fig. 1.1. There are a number of key features in the processes that the students go through. These include:

- **Generation of ideas**. A key differentiation of how the course is organized is the development of ideas by the students to form their own product. This is a carefully orchestrated process where the course developers apply encouragement, honest feedback and engagement to the students and the sales and marketing, IP and business experts help them hone

the development of an idea (or ideas) that have commercial viability. The students also have to utilize their engineering skills as this provides both a basis on which to develop the product and a commercial advantage in pushing the business case. The processes by which students are encouraged to generate novel ideas are covered in detail.

- **Interaction with business experts**. In the development of the course, we have instigated a number of interactions with business experts with expertise in branding, marketing, IP assets and finance. These experts act in confidence, providing business advice and guidance initially through tailored presentations and then in one-to-one clinics to provide detailed advice to the students.
- **Business creation**. The groups are encouraged not only to create a product for a critical need, but also to undertake a detailed exercise in creating a company to support the development, marketing and sales of the product. This course provides all of the background to the students to create a professional commercial pitch which in many cases can be used as the basis for their final pitch in a business competition.
- **Technical guidance**. A clear need is to ensure the students can provide enough evidence to show that a product is viable. This not only garners confidence in their idea but also provides a focus for a *wow* factor in their presentation. This process involves interaction with technical experts, that is engineering academic and technical staff within the faculty, to iron out any technical issues with regard to creation of their product.
- **Product demonstrator**. The development of a working prototype ensures a practical validation and confirmation of their business projections. It also provides an initial cut-off point for their course but also a starting point for any future business development.

1.7 Breakdown of Book Material

The material for the course has been organized into separate chapters which act to cover each of the topics illustrated in Fig. 1.1. The organization for this is demonstrated in Fig. 1.2.

Chapter 2, entitled *Idea Generation, Filtering and Development*, gives an outline of the processes and mechanisms by which the critical ideas are identified and refined by the group. As Fig. 1.2 shows, a number of possible ideas are created and the group go through a series of examination processes based on market potential, standards and regulation, morality issues, protection of ideas and future product options. This rigorous, demanding approach allows the students to identify if their initial ideas are promising. The chapter outlines in detail the steps taken, including examples of both potentially excellent ideas which can fall short because of a single critical issue in sales or commercialization or which can only benefit from detailed scientific knowledge. Given the length of the exercise and the experience of the students, projects with detailed scientific knowledge are therefore beyond the scope of the exercise. The text covers the process by which students come up with initial ideas, receive detailed feedback and then look to brainstorm to generate new, better ideas that will stand up to increased scrutiny.

The next stage of the book gives details on how to develop the necessary business material and comprises two chapters, namely *The Ideal Pitch* (Chapter 3) and *Creating an Effective Business Plan* (Chapter 4). In Chapter 3, we demonstrate how market potential, sales, finance and IP issues can be vital in determining the product pitch and give an example from which

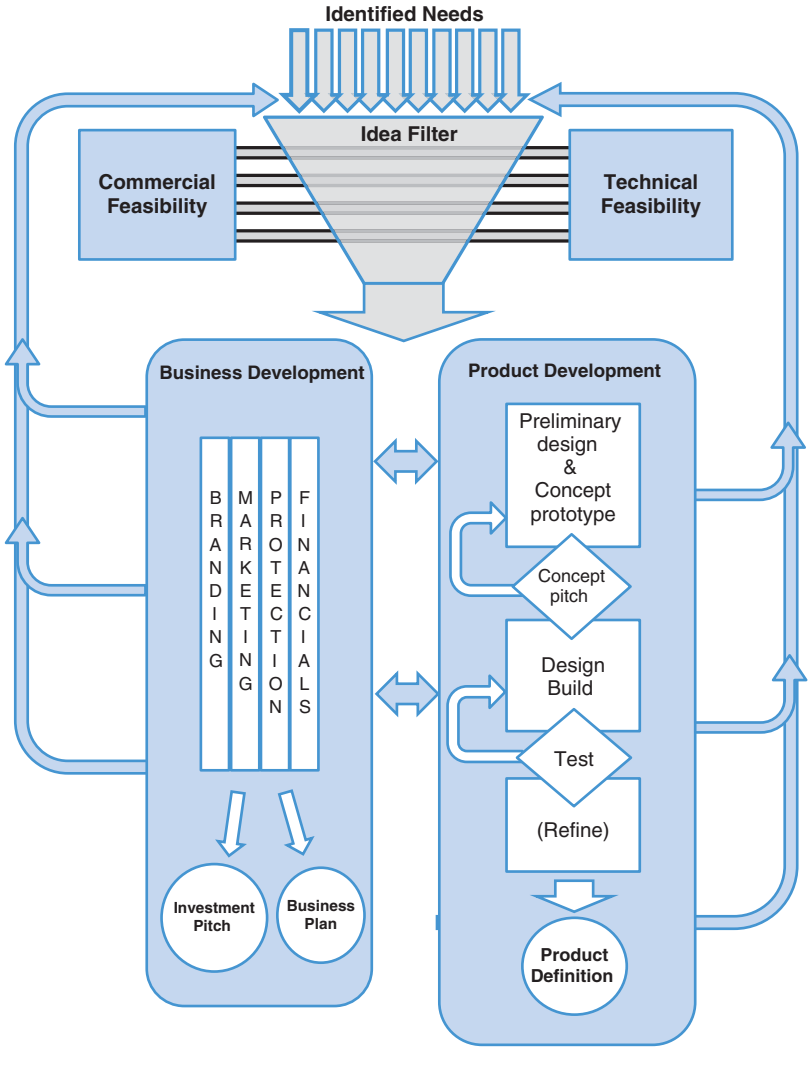

Figure 1.1 The commercialization process

students can produce their own presentation. The students are encouraged to try to put this pitch together as early as possible in the exercise; this allows them to quickly identify their best product idea by highlighting any possible areas of weakness. The 15-minute pitch unashamedly builds on the highly successful CONNECT programme developed in San Diego and now organized in the Northern Ireland Science Park. The detail in the business plan in Chapter 4 demonstrates to prospective company creators how they should identify a market opportunity and develop an engineering solution with the aim of creating a viable product. It highlights the need for consideration of branding, marketing, IPR and finance, which form the material in the next group of chapters.