Education in Chemical Entrepreneurship: Towards Technology Entrepreneurship for and in Chemistry-Related Enterprises

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Abstract

This paper reports design experience and execution of the authors' curriculum entitled "Chemical Entrepreneurship", actually dealing with "technology entrepreneurship emphasizing chemistry-related enterprises", and being multi-disciplinary. Uniqueness of the curriculum shows up in its scope and addressees concerning age and levels of experience. The attendees are scientists and engineers and exhibit a broad spectrum, from university students and researchers to academic (Dr/PhD) personnel of a national research center. The pioneered "Theory-to-Practice" curriculum may serve as a new model for teaching technology entrepreneurship and intrapreneurship (entrepreneurship for firm foundation and in established firms) in an integrated fashion within a systems-, process- and intelligence-oriented theoretical framework. This includes an elaboration of the specifics of technology entrepreneurship as opposed to "non-technical entrepreneurship" and also emphasizes distinct country-specific factors of technology entrepreneurship, particularly financing and networking, through national science and technology, policy and industry systems and their interactions. Additionally, the curriculum covers also training of "soft" skills, such as presentation skills.

Key words:

Curriculum, education, technology entrepreneurship, intrapreneurship, innovation, intelligence, theory, systems, "theory-to-practice"

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1. Introduction

The present contribution will report the "why, what and how" of a curriculum of "Chemical Entrepreneurship" [1], actually dealing with "technology entrepreneurship emphasizing chemistry-related enterprises". Additionally, experiences gained with a course delivered in Winter 2007/2008 for the first time at the University of Karlsruhe (TH) in Germany in the context of the recently created Karlsruhe Institute of Technology (KIT) organization (Remenyi 2007) [2]. Fundamentally, KIT is the (organizationally completed, but legally still to be achieved) merger of the University of Karlsruhe (TH; Technical University) and the National Research Center and Laboratory in Karlsruhe (FZK: Forschungszentrum Karlsruhe) [3]. With around 8,000 employees (ca. 4,700 academic personnel) and an annual budget of 676 million Euros, KIT aims to become a leading institution in selected science and engineering disciplines in the world. Strange to say, though the (Technical) University of Karlsruhe has an institute dealing with entrepreneurship ("Interfakultatives Institut für Entrepreneurship" (IEP) – Interfaculty Institute for Entrepreneurship), there were no dedicated technical (technology) entrepreneurship programs.

The prospect of the curriculum relates specifically to an *elective* within an (anticipated) Bachelor/Master chemistry study and will be associated with ECTS (European Credit Transfer System) credit points. The curriculum to be presented does not only follow the growing trend to design courses specifically for non-business students. Therefore, at first the scope, framework and goals of the "chemical entrepreneurship" curriculum and its underlying situation and directing orientations shall be elaborated.

It is generally agreed that entrepreneurial behavior remains a crucial engine of innovation and growth for the national economy and for individual companies. The increased focus of policy on entrepreneurship as a basis for new firm foundations, particularly new technology-based firms (NTBFs), job creations and societal wealth is paralleled by corresponding national governmental and federal state programs, initiatives and incentives for firm foundations (see also below Figure 1). Additionally, there is interest in identifying policies that may enhance the level of entrepreneurial activities which, in particular, led to an increased focus on entrepreneurial programs and establishments of university chairs for entrepreneurship, usually in the economy/management/business administration fields. And policy (in Germany) requests from universities that "students must get the necessary knowledge and tools for stepping into self-employment" (Schmude 2007: 5).

A relatively recent trend in entrepreneurial education is programs directed at science students and so-called research-based startups (RBSUs) (or "academic startups" (ASUs)), spin-offs from a university or other research institute (Bantel 2003; Gottschalk et al. 2007). This implies a more distinct differentiation of "academic entrepreneurship" versus "technical entrepreneurship" (Tidd, Bessant and Pavitt 2001:352). In this line, there are also a growing number of entrepreneurship education programs that are developing integration with university technology transfer offices and/or incubators (Bantel 2003).

Furthermore, also scientific societies, for instance, the American Chemical Society (ACS) or the German Chemical Society (GDCh), take increased interest in the subject which is reflected in recent publications in their respective member journals (Arnold and Kraft 2007; Ember 2000; Festel and Klatt 2006; Festel and Terzenbach 2007;

Hauthal 2005; Stinson 1999; Zbikowski 2006a, Zbikowski 2006b). And in particular, in 2007 the GDCh Special Interest Group "Association for Chemistry & Industry" ("Vereinigung für Chemie & Wirtschaft") organized idea contests for young university chemists and provided related knowledge whether and how they can transform an idea into a business plan and a startup.

Finally, with regard to chemistry and "academic entrepreneurship" and "Research-Based Startups" (RBSUs), a study of the Royal Society of Chemistry (RSC) on RBSUs from twenty-nine universities in the UK revealed (Moustras 2003), for instance, that

- Chemistry as a university discipline appears as productive as any other discipline
- 48% of chemistry spin offs are joint with other disciplines ("multi-disciplinarity" including bio-scientists – 69%, engineers – 38% and materials and IT specialists – 15%)
- Two key factors inhibiting academics from spinning out companies are 1) pressure of their day job and 2) inexperience.

2. Technology and Chemical Entrepreneurship Specifics

Entrepreneurship can take the perspective that it is related to technical and non-technical (behavioral or organizational) innovation, shows up outside and inside established organizations ("intrapreneurship") and covers business and non-business activities. In particular, we see it as a combination of human, technological, venture and environmental conditions.

For educational purposes we use a *theoretical framework* and regard entrepreneurship fundamentally as a *process of creating socio-economic value in the context of interrelated systems*, referring essentially to the defined sub-processes depicted in Dorf and Byers (2007: 28) and Morris, Kuratko and Covin (2008: 104). In particular, the process driven approach is adopted to identify possible inputs which are likely to be required to produce the elements of a business plan. Furthermore, a *systems* approach is generally emphasizing the *continuous changes* of the involved systems which initiate or require, respectively, permanent adaptations of sub-systems in line with conditions and forces exerted by the super-ordinate system(s). Hence, for entrepreneurship we look at traits, attitudes, behavior, decisions and actions of individuals with certain theoretical and/or practical knowledge in a scientific and/or technological domain under situational constraints or drivers, respectively. And as a consequence, entrepreneurship and innovation is intrinsically bound to "*intelligence*" – knowledge and foreknowledge of the world around us as the basis for decisions and actions (Runge 2006: 520). Hence, characteristics of the individual(s), the business idea/opportunity and the environment interact with the types of entrepreneurial sub-processes and influence executions and outcomes of the sub-processes and finally the overall process.

Figure 1 exhibits situational influences by an "onion-like" model of entrepreneurship as a generic "core" of features and sub-processes embedded into (and across) shells of super-ordinate systems which may exert essential influences onto the core, for instance, on attitudes, decision-making and actions. And entrepreneurship occurs as a function of the interactions among a number of key endogenous variables and exogenous parameters (Runge 2006: 9). In this way, entrepreneurship of individuals in established firms is, among other things, constrained by power of executive management, types of leadership, corporate culture, corporate business processes, corporate routines etc. (Morris, Kuratko and Covin 2008) to emerge as "intrapreneurship".

Theory orientation of the course proceeds even down to the micro level, but not explicitly to research that concerns psychological traits and other personal dispositions of entrepreneurs. Instead, explicit references are made to psychometric studies, for instance, in terms of the Myers-Briggs Type Indicator (MBTI®) broadly known for new hire personality testing and team building. These are used to introduce generic type differences between "innovators/intrapreneurs" versus "managers" to show how potential conflicts may arise and correspondingly barriers for entrepreneurial activities in firms.

Furthermore, a considerable amount of entrepreneurial activities in terms of firm foundations sprouts out of existing firms, not just planned company spin-offs, but establishing new independent enterprises by employees who leave a firm (Kourilsky and Walstad 2002: 10), as they

- see their ambitions and progress blocked in big corporations,
- have "adaptive persistence" which allows people in existing organizations to anticipate disruptions to the market and to recognize opportunities (where the firm people leave may even be an NTBF),
- encounter unfavorable organizational situations (layoff, closure or selling of the firm or a business unit, etc.) to generate "necessity entrepreneurs" as opposed to "opportunity entrepreneurs" (Bosma and Harding 2007:15).

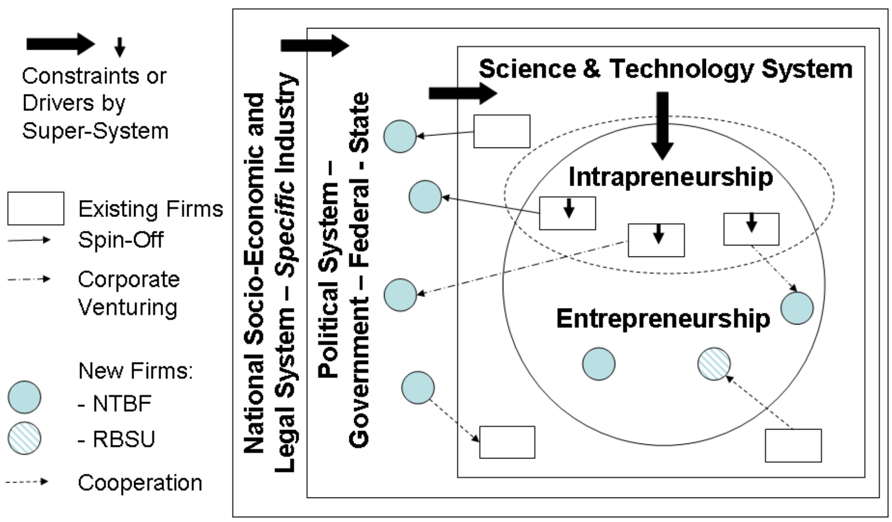

Figure 1: Key "shells" of constraints and drivers for technology entrepreneurship

The first two points reflect to a certain degree just the opposite direction of the above mentioned emergence of intrapreneurship: here, (blocked) intrapreneurship leads to entrepreneurship. The last aspect of organizational situations may also include conflicts with investors which let firm founders leave their firms (sometimes to found a new firm and thus become a "serial entrepreneur"). All these effects can be assumed to, at least partially, influence the average age of NTBF founders (see below).

Apart from drivers by national policy (programs, initiatives, incentives etc.) innovation and entrepreneurship for founding NTBFs or RBSUs can be associated with effects of the national science and technology system, the particular scientific/engineering discipline and the specific related industry including the modes of interactions between existing and new firms, such as cooperation and various forms of alliances, or funding and ownership through corporate venturing. Such an approach introduces more *country-specific features* into (technology) entrepreneurial education than is commonly found in "standard" textbooks (e.g. Dorf and Byers 2007).

The above outlines of understanding implied major consequences for the design of the entrepreneurship curriculum. Notably. the scope of the curriculum will comprise entrepreneurship to found new firms as well as entrepreneurship in established firms ("intrapreneurship"). Our interrelated and integrated entrepreneurship and intrapreneurship orientation of entrepreneurship education is in line with the structural orientation of the Technological Innovation & Entrepreneurship (TIE) Program of the MIT Sloan School of Management (of the Massachusetts Institute of Technology - MIT) [4].

The focus also on intrapreneurship provides an additional rationale when relaxing certain constraints of the specific corporate environment, such as corporate culture or routines (Figure 1). Intrapreneurship, emphasizing innovation to increase profits and growth of large companies, is at the center of business and management research. Hence, it provides established approaches, tools, and skills ("best practice") managing entrepreneurial firms when, in the course of their development, they attain the point of growth (after ca. 4 years or sales of ca. \$5 mio.) which requires "professional management" for further development. In particular, the New Business Development (NBD) process and innovation according to a StageGate® process in large companies are structurally rather close to management in entrepreneurial firms.

Furthermore, the special organization of the KIT will have to consider and interrelate "academic" and "technical" entrepreneurship and target RBSUs and NTBFs, respectively. And, additionally, the special structure of KIT's personnel makes addressees of the curriculum very heterogeneous:

- (To be) scientists and engineers
- Advanced students, (post)graduated students, academics and faculty members typical for a university,
- Graduated and doctoral researchers and engineers and academic personnel of a national laboratory, (partially) with experiences in applied sciences, project work and cooperation with industry
- Alumni.

However, technology entrepreneurial education and training to all age groups should, in general, be common rather than exceptional, as it was found that the average and median age of NTBF founders was 39, contrary to a popular belief that "tech entrepreneurs" start their companies in their teens or early 20s (Wadhwa 2008). This is in agreement with Colombo and Delmastro (2002: 1113), Kourilsky and Walstad (2002: 5) and with Co (1999) who reported that (many) technical entrepreneurs have relevant experience (on average 13 years' work experience before establishing an NTBF; age between 30 and 40 years).

Specifically for RBSUs entrepreneurial professors often show up as founders or co-founders, respectively, of firms. The challenge, hence, is to have course attendees in one class with a broad range of age, educational level and experiences. Still open questions for the present curriculum are in how far it has to be related to the KIT incubator organization which is under development or should focus on KIT's key subject orientations (nanotechnology and energy).

The notions "chemical" or "chemistry-related enterprises" in the curriculum title requires further consideration. Basically, it is often assumed and even more generally shown that entrepreneurship for technical areas to found new technology-based firms requires discipline-specific approaches. For instance, 87 percent of NTBF entrepreneurs believe that training for technology entrepreneurs needs to be specialized, to reflect the unique challenges of the discipline (European Commission 2003; Gangemi and DiMeglio 2005; Mitchell and McKeown 2004). Correspondingly, there is increasing orientation towards "technology entrepreneurship" (Dorf and Byers 2007) or "technical entrepreneurship". The last one refers essentially to engineering rather than scientific orientations (e.g. Cooper 1973; Tarjan and M. Lenart 2000) and is usually associated with engineering school entrepreneurship programs.

But what does the notions "chemical" or "chemistry-related enterprises" actually mean in terms of scientific or engineering disciplines as practiced in (technical) universities, research institutes and industry in the context of entrepreneurship and innovation? Chemistry shows up as a scientific discipline with many overlaps and interfaces to other fields and applications for a myriad of areas of day-to-day life; and the chemical industry exhibits co-evolutions with many other industries, such as textiles, paper, automotive, oil, food, electricity and electronics, water, energy etc. (Runge 2006). Current innovation orientations of the chemical industry exhibit strong trends towards "multi-disciplinarity", which is also reflected by the types of RBSUs spun-out from universities in the above mentioned RSC study.

Consequently, attendees of a "chemical entrepreneurship" curriculum can be envisioned to be related essentially to chemistry and chemical engineering, but also to a breadth of industry-relevant chemistry-based or -oriented areas, such a instrumental analytics (for instance, for chemical nanotechnology and materials sciences), with people often from applied physics or chemical physics, biotechnology ("white biotechnology"), or specific engineering and materials fields interwoven with chemistry, such as (micro)electronics (organic semiconductors, printed electronics), photonics and lighting (OLED – organic light emitting diodes), energy (photovoltaic and organic solar cells, fuel cells and batteries, biofuels and biorefineries, hydrogen storage), and even cheminformatics (Runge 2006). Hence, the field under consideration is multi-disciplinary per se rather than narrow as chemistry is usually being teached in universities. And it may be "high-tech", but not related to computer science or information and communication technology which are currently in the focus of technology entrepreneurship (Dorf & Byers 2007; Kourilsky and Walstad 2002).

Entrepreneurship in scientific and technical areas differs often from non-technical areas in its origins, which mean its initiating steps for the overall process. This requires a certain shift in emphases for entrepreneurial education. In our technology entrepreneurship education approach, there are three initiating categories "idea", "chance detection or discovery and serendipity" and "opportunity" which are treated as principally independent and have to be interrelated and "channeled" into further entrepreneurial processes and actions. In technology entrepreneurship more than often having or generating an idea is separated from identifying the (business) opportunity. For instance, it was shown that in existing firms a very high proportion of individuals who generated the ideas did not recognize the opportunities (Leifer et al. 2000: 37). And specifically, when (inorganic) chemistry began in 1704 in Berlin (Germany), the chemist and "color maker" H. Diesbach found "Berlin Blue" ("Prussian Blue") by serendipity. Diesbach told his "raw material supplier" C. Dippel about his observation and Dippel immediately recognized the commercial potential of the disruptive innovation. Even after 200+ years "Berlin Blue" can still serve as a fundamental case for *generic* features and structures of innovation and entrepreneurship in chemistry (Runge 2006: 397). Moreover, it introduces the very *important role of chance detection or discovery and serendipity* in chemistry and other scientific and technical disciplines for innovation, entrepreneurship and intrapreneurship (Runge 2006). Serendipity is finding something unexpected and useful while searching for something else entirely (Runge 2006: 430). In particular, reference to historical cases let generic features and processes of innovation and entrepreneurship appear lucid to students.

Furthermore, innovation and entrepreneurship in the technical arena may occur as a "demand (market) pull" or "technology push" mode (market needs versus technology application options). Additionally, disruptive innovations or "technology push" approaches (both possible through startups) require often consciously "creating" or developing a (so far non-existing) market rather than responding to demands of an existing market (Leifer et al. 2000; Runge 2006).

A further feature differentiating technology entrepreneurship and NTFB foundation and emergence from founding non-technical firms concerns resources for entrepreneurial action, in particular, *financing*. Apart from personal savings and 3F ("family, friends and fools") funds financing an NTBF does not only refer to the "common" private capital sources and public policy programs to support firm foundation. Often financing and maintaining NTBFs or particularly RBSUs has an important second component: *research projects and grants* whether provided via national or federal state governmental (or even trans-national, European) "Science & Technology Programs" or research supporting organizations like the NSF (National Science Foundation) in the US or the German Science Foundation ("Deutsche Forschungsgemeinschaft" – DFG).

In this regard and apart from differences in the national socio-economic system, through the role of the national Science & Technology System and policy orientation, technology entrepreneurship gets another *country-specific drive*. Moreover, the interconnections of the (national) Science & Technology System, industry and policy can generate *intangible resources* for entrepreneurship and sources of competitive advantage having to do with *network generation* and ties and *cooperation between industry, universities, research institutes and policy*. For instance, in a study initiated by the German Industry Association concerning networking, (after Japan) Germany takes the second position; the US position is fourth (DIW 2007). Though attitude towards risk and risk taking may be culturally ingrained risk management for entrepreneurial education will have to elaborate and exhibit the overall country-intrinsic systemic factors which may allow assisting the would-be entrepreneur in dealing with risks and uncertainties which surround any new business venture.

To summarize, technology entrepreneurship/intrapreneurship education must clearly and explicitly differentiate and teach generic structures, features and processes and their "expressions" through systems' conditions and forces, for instance, through country-specific conditions. Rather than educating "about" entrepreneurship and enterprise the current curriculum aims at *educating "for" (technology) entrepreneurship under defined constraints and drivers* based on a theoretical framework of entrepreneurial initiation (ideas, ideation, chance detection and serendipity) and subsequent processes emphasizing intelligence, in particular,

- opportunity specific knowledge: the knowledge about the existence of an unmet demand/market and/or about the resources and mixing options of resource types needed for venturing in it;
- uncertainties and risk specific knowledge: the knowledge about uncertainties and risks and how to deal with them to proceed with decisions and actions,
- venture-specific knowledge: the knowledge on how to produce or provide a particular offering.

Concerning scope and content all these considerations set technology entrepreneurship and particularly "chemical entrepreneurship" apart from how it is currently approached. The term "Chemical Entrepreneurship" has got significance since at least 1988 when the American Chemical Society held a "Conference on Chemical Entrepreneurship" (American Chemical Society 1988). As to the knowledge of the authors, so far there is only one regular course dedicated to chemical entrepreneurship. The course at Cornell University in the US (Stinson 1999), originally entitled "Chemical Entrepreneurship" and now entitled "Entrepreneurship in Chemical Enterprise", is taught always during Spring semesters for chemistry majors and is organized essentially through the Institute of Organic Chemistry (Prof. Bruce Ganem). The course consists of six weekly 90-minute meetings [5]. On the other hand, in the context of the Texas Tech University's Welch Summer Scholar Program it was reported to have "experimented with two learning modules that focused on chemical entrepreneurship" [6]. However, the authors are unaware of any results from these experiments. Additionally, in the context of enterprise education for students pursuing degrees in science or engineering, at Heriot-Watt University (UK) for those studying chemistry the same arrangement concerning entrepreneurship electives has been made as has been etablished for IT (Galloway and Keogh 2006). An enterprise module (on idea generation and commercial proof of concept) provides students the opportunity to develop enterprise and business skills and access to entrepreneurial role models via guest presentations. Therefore, the "Chemical Entrepreneurship" curriculum provided at Karlsruhe University (TH)/KIT through the Institute of Organic Chemistry with support of the "Interfakultatives Institut für Entrepreneurship" (IEP, Interfaculty Institute for Entrepreneurship) seems to be the first one in Europe.

A different entrepreneurship approach for the chemistry area is used by Case Western Reserve University (CWRU), Cleveland/Ohio, in conjunction with the university's Science and Technology Entrepreneurship Program (STEP). CWRU encourages chemistry students to get a Professional Science Master (PSM) through STEP, which offers a focus on chemistry for entrepreneurship [7]. The Professional Science Master's (PSM) degree is a relatively new type of graduate degree. It is a targeted study in chemistry with practical business instruction and practice. The program provides studies in technology innovation and state-of-the-art chemistry, and real-world entrepreneurial experience. The Master of Science in Chemistry Entrepreneurship is a 2-year master's degree offered by the Department of Chemistry.

Finally in 2006, Northeastern University of Boston (MA) has established a School of Technological Entrepreneurship (STE). STE offers both undergraduate and graduate programs that teach students how to create business plans, market science- and engineering-based products and obtain the financing to start a technology-based business and covers important topics needed to know in a technology-based business world. STE offers science undergraduates, such as chemistry majors, a minor in technological entrepreneurship. The new minor requires a total of 5 courses [8].

3. Curriculum Orientations

3.1 Objectives and Scope

The objectives of the "Chemical/Technology Entrepreneurship" curriculum are as follows. For students, faculty members, researchers and other academic employees of KIT increase awareness about technology entrepreneurship and innovation and support mentality/motivation as well as readiness and behavior for founding new technology-based firms in the field of chemistry and related scientific and engineering disciplines through provision of education and skills using appropriate educational and training methods, tools and materials following a "Theory-to-Practice" approach. Furthermore, related to the currently changing industrial environment, students shall be prepared to follow top job tracks in industry. In this regard, the intrapreneurship part of the curriculum will provide the fundamental structural options of organizing industrial research, but also the means to familiarize attendees with the realities of innovation as well as research and development in the modern enterprise.

The expected result is more chemists and chemical engineers and other scientists and engineers who are empowered to innovate and commercialize technology, either as entrepreneurs creating and growing new companies or intrapreneurs working within established companies or research institutes in areas of innovation, research, as well as New Product Development (NPD) or New Business Development (NBD). Our entrepreneurship education will not be based on the false expectation that a distinct proportion of attendees will go on to start businesses, but rather that they will benefit from enhanced creativity and enhanced personal attitudes towards change, entrepreneurial thinking, behavioral changes, decision-making under uncertainty and risk, and employability. Finally, it should be shown to young people "that entrepreneurship isn't just about business; it's a way of life" (Gangemi 2007) focusing on self-direction.

One specific learning objective (and issue) is to increase understanding of the special business language used in the context of entrepreneurship by all the people involved in commercialization aspects, but also technical innovation, such as folks of market research, intelligence and marketing, business analysts, investors, bankers, etc. As the actual language in this context is to a large extent governed by terms and phrases in English and , in Germany, a sloppy mixture of German and English (called "Denglisch"), it was decided to keep the English notion "Chemical Entrepreneurship" and provide lecture scripts and slides in English, but to provide the course in German. Questions during the course could be asked in German or English, the instructor's answer would be in the question's language. Additionally, this approach is assumed to support foreign nationality attendees of the course.

The "Theory-to-Practice" approach means that the overall course balances theoretical, practical and practitioner education and is linked, for instance, to real-world cases providing attendees to a thorough exposure of the many concepts and building blocks of entrepreneurship. It also includes training of "soft skills", such as presentation skills. The fundamental orientation towards a Theory-to-Practice course means that it is not a business school MBA-type approach with some addition of technology examples or a transformation of an MBA-education oriented course to technical disciplines. It focuses on technology with the provision of only the absolutely necessary basics of business concepts and notions. Science and engineering majors will learn the essential pieces critical to building a high-tech business ("*need to know approach*"), to understanding enough of the concepts and the language so as not to be mystified and, finally, to ask the right questions and knowing whom to ask.

In the context of technical innovation the notion "gatekeeper" was revived as an interface, if "differences between intervening parts are too large to allow direct contact and/or communication between the parts" (Runge 2006: 9, 783), such as interconnecting various scientific and technical disciplines or corporate-internal and external research - or the corporate research and marketing functions or science and policy. For this role also the notion "boundary spanner" is common (Williams 2002; Wright et al. 2005). For the current curriculum the teacher/instructor fills the boundary spanning role in several regards. As an experienced (German) scientist (with several dozen publications in internationally leading chemical journals and the typically German "Habilitation" degree which is a prerequisite for a university career in Germany), eighteen years experience in the US chemical industry in various jobs and roles and currently in management consulting for innovation, research and technology intelligence) he spans academia and industry, theory and practice, technology and commercialization and finally also different cultures (German vs. US-American). Though this instructor (adjunct) characteristic looks exceptional and special, we feel that a similar profile would be generally advantageous for teaching technology entrepreneurship, as it allows more detailed discussions with attendees about options and paths to commercialize (their) technical ideas or discuss cases of technology ventures in technical *and* commercial details.

Considering that the majority of anticipated course attendees will be advanced students/graduates and post-graduates and academic personnel (with diploma or doctoral degrees) in physical sciences or engineering one course goal was to achieve the most with a minimum of efforts for the attendees. Pressure of their day job, academic duties or engagement in the mainstream study let us suspend "reading lists" (directed reading) for successful course attendance. Instead, it is the intention that attendees grasp the content relying only on course scripts and the actual lectures, though course scripts contain ample references for further reading and details. Almost 90 percent of the references or suggested readings of the course are made to just one book (Runge 2006), the rest to two "standard" text books (Dorf and Byers 2007; Tidd, Bessant and Pavitt 2001).

3.2 Curriculum and Course Character and Educational Toolbox

Having outlined the framework of the curriculum the educational toolbox shall be presented. Many entrepreneurs and educators agree that entrepreneurial awareness, skills and behavior cannot be taught with only lectures and multiple choice examinations. Some form of experiential learning is necessary for aspiring entrepreneurs to learn how to effectively generate technology-related ideas ("ideation"), identify market opportunities, secure talented personnel, capital and other resources needed to exploit the opportunities, execute their business plans, and manage the risks inherent in any new venture. However, Fiet (2001) underlines the need not to forget the *relevance of deductive learning*, meaning that traditional lectures based on theory should still represent the core of entrepreneurship courses.

For teaching the curriculum is based on a course and workshops, both modes involving Participant-Centered Learning (PCL). The course adopts a *lecture* approach focusing on (NTBF) *cases* to underpin general concepts, but also special approaches and issues in the company's development; however, without related “reading lists” for students. Lectures are occasionally interrupted for ten minutes for *dialogues and “group discussions”*, usually to elaborate concepts, classifications and issues based on selected short texts provided to the attendees during the preceding lecture. Practical business instructions for particular situations are interspersed into the lectures in terms of “*check lists*”, often formulated as questions and sometimes generated interactively with attendees.

Cases in the context of technology entrepreneurship are also important to introduce the *taxonomy of technologies*, such as platform, generic, enhancing, enabling, pacing technology etc. (Runge 2006: 621), and to elaborate technology type related commercialization strategies as well as competitive positions (“opportunities and threats”). This transformation of “academic knowledge” into “practitioner knowledge” (Davidsson 2002) represents a typical example for the current “Theory-to-Practice” approach.

The cases provide a further construct for successful implementation of our pedagogical strategy. A “complete” case in our particular situation includes also *biographies* or biographical “snapshots” (“*story-telling*”), which is narrative knowledge and often reflects non-linearity of entrepreneurial processes and decision-making (Fillis 2007). Biographies can be used as role models and substitute for personal advice for entrepreneurs. A number of chemistry-related entrepreneurial biographies are found in Runge (2006). And in the UK on its “Support for Small Business” Web section [9] the Royal Society of Chemistry provides also biographical information in the sub-sections “Meet the Entrepreneur” and “SME of the Month”.

To “experience” entrepreneurship invited guest speakers from industry provide lectures (in German) on innovation, new business development and the intrapreneurship part of the course [10] as opposed to guest lectures of “real” entrepreneurs [11]. The entrepreneurs provide special cases with entrepreneurial biographies, backgrounds and founding constellations and generate further insights through Q&A in completing the lecture or in meetings with the entrepreneurs after the lecture. Students appreciated in particular the emotional and subjective parts when entrepreneurs spoke about threats for the existence of their startups, personal errors and failures and advices and assessments concerning political startup programs and financial backers for the startup.

Concerning content, the course follows a *modular approach* with fourteen weekly 90 minute meetings including four lectures by guest speakers. The “permanent” thirteen modules presented by the KIT instructor are given in Table 1. In the sense of MIT Open CourseWare all the lectures are publicly accessible via the Chemical Entrepreneurship Web site.

The course modules are “*self-sufficient*” and refer to multiple business disciplines (Table 1): strategy, management, market research, marketing, and finance and associated technology disciplines (ideas and opportunities, technology intelligence, technology innovation, patents and intellectual properties, new product development, new business development) as well as clustering (industry, technology and science parks) and networking. The module structure reflects the process driven approach and has been designed with the "environment model" (Figure 1) as the framework towards creation of a business plan, such that the dedicated module (11) appears as a summary and extension of the preceding modules (Table 1). In the course, all the advantages of having (or needing) a business plan are emphasized in several contexts. However, it is also emphasized distinctly that entrepreneurship and ventures do not initially need a business model or even a business plan to become successful.

An advantage of working with "self-sufficient" modules is that students may choose to attend the course selectively according to topic, for instance, attending the module on "ideas, opportunities and strategy" or patents or technology intelligence. A further rationale is to make the course also attractive for students from other disciplines and other academic people from KIT interested in just a particular topic. On the other hand, the modular approach requires a certain level of redundancies to help attendees of single modules to grasp the essentials. However, this apparent shortcoming of redundancies can be turned into an advantage for the special course under consideration as a means of supporting learning. *Redundancies* have been set up as a "*revolving approach*" discussing a particular topic in different contexts. This is introducing some topics in a spiral fashion, with "preview" and "review" sections in different modules.

Table 1: Modules for Chemical Entrepreneurship

Style	Modules and Course Content
Lecture, Group Discussion	(1) Preliminary Remarks; Introduction – Setting the Stage
Lecture (2 Modules)	(2) National Economic and Science & Technology Systems and GEM (The Global Entrepreneurship Monitor); (3) Startup Life Times and Personal Traits of Entrepreneurs
Lecture	(4) Ideas, Opportunities and Strategy
Lecture	(5) Patents and Intellectual Assets
Lecture, Group Discussion	(6) Entrepreneurship and Technology Intelligence
Lecture (2 Modules)	(7) The NTBF Startup Phase: Operational Competencies, Resources and Innovation Architecture/Configuration; (8) Clustering, Networking and Alliances for Startups and NTBF
Lecture	(9) The Entrepreneurs' Market Research and Marketing
Lecture	(10) Basics in Financial Understanding
Lecture, Group Discussion	(11) Commercialization Models, Business Models and Business Plans
Lecture	(12) Differences between Small and Large Firms; (13) Intrapreneurship: Company Requirements and Barriers for Entrepreneurial Activities

For the course there are two types of credits. An “Attendance Confirmation” (“Teilnahmebescheinigung” in German) can be issued if a minimum of 70 percent of the lectures (10 of 14or 11 of 15) were attended. On the other hand, there is a “Certificate” (“Leistungsschein”) associated with four ECTS (European Credit Transfer System) points. To be eligible for the Certificate the candidate has to pass a written multiple choice examination (with 90 questions in English referring only to contents of the “regular” lectures, not lectures by guest speakers). Furthermore, candidates are required to write a 10 minute, (maximum) 5 slides presentation of a business plan in German or English with “2 Persons Groups” being allowed. The “short business plan” has to be created as a Microsoft PowerPoint or Word file, but has not to be presented verbally as part of the examination (see below; Figure 2).

To “experience” entrepreneurship through venture plan writing, the “business plan examination” requires students to extract a business plan from documents of *real startup cases*; it does not refer to subjects or projects initiated by students. The cases provide descriptive examples of, for instance, financing startups and business ideas and models, firm revenues etc. and presents “stories” of entrepreneurship that shall generate awareness, motivation and inspiration for potential entrepreneurs. Fifteen case documents for German and also international startups, sometimes together with “auxiliary files”, have been generated from only Internet sources and provided to the candidates giving them first-hand experience in analyzing business situations. The document text is unstructured and sometimes redundant and can even contain irrelevant material. It may not provide explicitly information that should appear in a business plan. If needed information does not appear in the case documents students are encouraged to obtain it through comparisons with other firms in the overall case set, to provide an “educated guess” or simply explain why this information is currently not available and how it will be gathered for further discussions or why this information is principally very difficult to obtain.

Using material from the Internet to create formally a business plan represents simultaneously a demonstration of the Internet as a source of business information and an instructional and learning approach for demonstrating the relevance of the commercial aspects of technology *intelligence* for entrepreneurship. Furthermore, it reflects typical input for the creation of “company profiles”, “market profiles” and/or “technology profiles” used in the corporate environment in the context of technology intelligence, competitor analysis, competitive technology assessment or marketing where the actual data/information set is usually generated in an unstructured manner by the corporate-internal or an external information (intelligence) service organization.

Using the information of the case document the emphasis of the short business plan presentation can be selected to focus on:

- A hypothetical foundation of the NTBF (startup) or
- An anticipated further financing round for expansion (“growth”) of an already existing NTBF.

The quality of passing the Certificate requirements will not be graded. The instructor performs only a qualitative assessment of the written business plan documents (“passed/not passed”).

The final aspect of the Theory-to-Practice approach to the course concerns important "soft skills" for entrepreneurs, such as presentation and negotiation skills or managing interpersonal relations and conflict. We have tackled this aspect in terms of workshops. For these and similar subjects the workshop format has been chosen, as it integrates intellectual and experiential learning using readings and understandings, presentations, group actions for elaborating concepts and structuring processes and discussions.

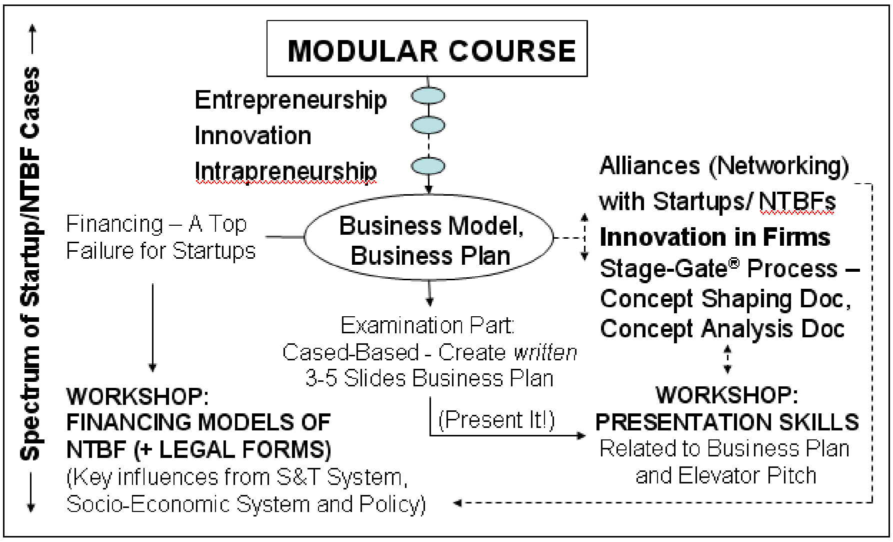

Figure 2: A structural model for the Chemical Entrepreneurship curriculum.

At present, the entrepreneurship program (Figure 2) includes two full-day workshops for the summer semester which, on the one hand, draws upon knowledge and material of the course and, the other hand, is an offer for voluntary participation of those who have familiarized with entrepreneurship through other means or approaches:

- "Special Presentation Skills for Entrepreneurship" - Learn and practice presentations focusing on a 10 minute business plan presentation, presenting a company profile and developing and presenting an „Elevator Pitch".
- "Financing Models of New Technology-Based Firms (NTBFs) including Legal Forms of Firms"

Figure 2 represents the central structure, key content orientation and educational tools of the Chemical (Technology) Entrepreneurship curriculum to be used as an elective for a Bachelor/Master track of a major in chemistry. In particular, it re-emphasizes the structural similarities of a (startup) business plan document and corresponding documents to be created in the course of a corporate innovation or new product development process through the now ubiquitous PhaseGate (Stage-Gate®) process in industry.

Figure 2 expresses also, on the one hand, the importance of alliances and networking of NTBFs or RBSUs with established firms for their strategies and growth and the roles of existing firms for financing NTBFs (for instance, through corporate venturing). On the other hand, it covers implicitly the roles of NTBFs/RBSUs for innovation and research of existing firms (Runge 2006; cf. also slide 18 of the BASF presentation [10]).

The case orientation does not only refer to the course (lecture and examination). Also the workshop on “financing models” uses the same set of cases that were available for the Certificate examination (see above). This particular workshop aims at responding to a key factor among startup failures and intends also to elaborate country-specific factors of technology entrepreneurship with practically relevant details. In contrast to the course the workshops require attendees’ preparations in terms of “directed readings”.

A final remark concerns the characteristics of slides used for the course. Slides for the course are identical with the lecture scripts, which mean they do not comply with “good presentation practice”. The slides contain often much text - with referral to the “standard” reference books. However, to emphasize key points of a particular slide during the lecture relevant terms or phrases are highlighted (“presentation bullets with a textual background”).

Rationales for this approach, which was viewed as experimental to test 1) whether this kind of approach is accepted and 2) how it is assessed, are as follows.

- Attendees will be confronted with a special language (“business administration”) with special terms and concepts they are generally not familiar with. Therefore, slides include often text (also full sentences) with explanatory character in the proper context to have “self-sufficient slides”.
- Scripts/slides are provided as paper handouts for own marking or highlighting and to make notes complementing the slide content (or term translations) to create an individually “annotated presentation”.
- It is a compromise between lecture in German and lecture scripts in English

The interest of the German chemical industry in education and skills specifically by this approach to “chemical entrepreneurship” was expressed through sponsoring. BASF and Evonik Industries [10] did not only provide financial support but participated actively in the course through guest speakers. Correspondingly, the firm von Hoerner & Sulger (vH&S) supported the efforts through provision of a guest lecture without compensation for travel and accommodation [11].

4. Results

Announcement of the curriculum was by common means of the university (dedicated Web site [1], university course catalogue, e-mail to selected faculty members and printed announcements on selected boards). Due to the low participation in the Certificate examination (Figure 3, Exam.; four participants who all passed the examination) students’ learning across the whole class cannot be reliably assessed. We had a further independent, but elementary degree of assessment of the design, content and the execution of the course through two anonymous questionnaires. Results from the relatively small samples were not subjected to any statistical procedures, but rather taken as “descriptive indicators”. Even though this seems to be a reasonable measure of satisfaction, we are aware that this kind of instrument does not state directly whether the participants learned anything (Alberti, S. Sciascia, and A. Poli. 2004).

After the first lecture a questionnaire focused essentially on

- Demographics of attendees (including discipline, gender, level of university eduction)
- Assessing the duality of English slides versus German talking

- Curiosity as a driver to attend the first course meeting and intention to whether or not continue attending the course
- Attitude towards entrepreneurship ("I have thought about founding my own firm").

The questionnaire after the last course targeted at the final assessment of the course and the assessment of the instructor using assessment levels on a five point hedonic scale with "counts" and "averages" of the responses as "results' indicators".

Main results of the questionnaire distributed after the first course meeting (20 respondents out of 31 attendees) are as follows. Attendees belonged by 90 percent to the Karlsruhe University part of KIT, only 10 percent originated with the Forschungszentrum Karlsruhe (FZK) part of KIT (which is physically located far apart from the university). Concerning gender ca. 30 percent of the attendees were female. The majority of attendees (ca. 50 percent) were advanced students with a post-bachelor level ("Vordiplom" in Germany) and on average eight semesters of study; ca. 30 percent had a master-level ("Diplom") and were engaged in a doctoral thesis. The remaining 20 percent of attendees were on a post-doc level with a doctoral degree. A large part of the attendees (70 percent) was driven by curiosity to join the first course meeting and about half of the attendees have already thought about founding their own firm (cf. also Kourilsky and Walstad 2002: 8). This was seen as a good chance to influence or improve, respectively, awareness, attitudes or even initiative towards entrepreneurship.

Concerning language 90 percent of the attendees were comfortable with lectures in German, but course material (scripts, slides) in English. Most of the attendees (85 percent) would not view questions during the lecture for word or phrase translations as disruptive. In particular, foreign nationality students (from France, Spain and Argentina and Canada) appreciated this approach.

In Figure 3 it is seen how attendees' population decreased from the "Start" (first meeting) with 31 people to 15 people in the last session ("End"; attendees eligible for the Attendance Confirmation). In the end about 30 percent of female attendees remained. In Karlsruhe after the fifth lecture meeting a relative stability of 13 attendees per meeting was obtained. The average number across all meetings (lectures plus guest lectures) was 18 attendees. This kind of decrease has also been reported for an "Entrepreneurial Development" course at Caltech (California Institute of Technology) where the number of initial attendees decreased from 150 to about 50 who stayed the course (Ember 2000).

Distribution of the scientific/engineering disciplines of attendees was obtained from the first questionnaire (Figure 3, Start). The discipline distribution for the "End" stage shows that 54 percent of the attendees were from Chemistry (27 percent) or Chemical Engineering & Process Engineering (27 percent). An interesting aspect is the fact that there seems to be a stable interest of students from Informatics (Computer Science), who represent 20 percent of the attendees. Disciplines of other attendees included, for instance, Electrical Engineering, Business Engineering or Food Technology. Finally, the four attendees who participated in the Certificate examination to obtain (ECTS) credit points for the (anticipated) elective (Figure 3) were from either Chemistry or Chemical Engineering & Process Engineering. Concerning the participation from science- versus engineering-based attendees it has turned out that in the "End" the vast majority came from engineering disciplines rather than science-based chemistry.

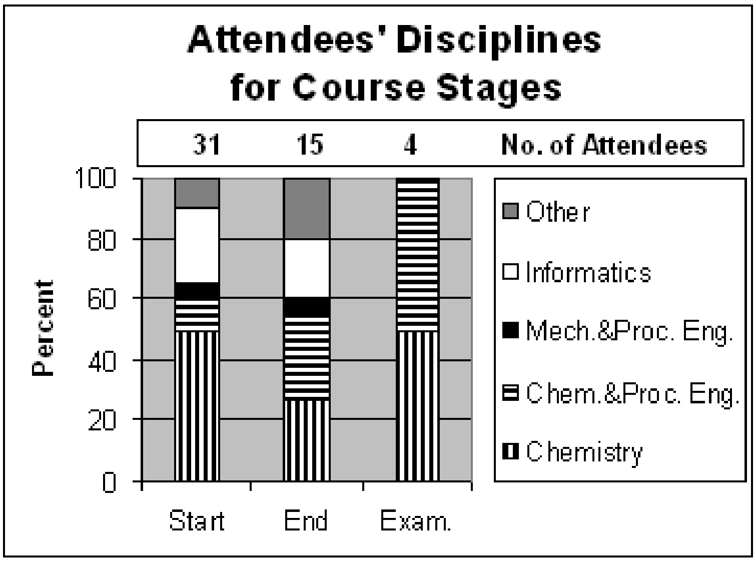

Figure 3: Development of attendees' course participation and their scientific or engineering disciplines.

As already found in the first questionnaire, the second questionnaire (10 respondents out of 15) corroborated many of the course design features and approaches (Figure 4).

The attractiveness of the course for people from non-chemical disciplines seems to be corroborated (roughly 50 percent of attendees are from fields not related to chemistry). When asked using a scale from 1 (Too much) to 5 (Too little) how much the course is related to chemical content the average answer was 3.0 (About right) with no extreme answers (1 or 5). The (welcomed) relative broad variety of attendees' disciplines for a course dedicated to "chemistry" by title can be partially, but tentatively, attributed to the modular character which allows students and others to selectively attend a meeting just of interest to them.

It does not appear as a surprise that a scientific/engineering population confronted with content which is far off their mainstream study or completed education viewed the content of the course as medium difficult (Figure 4; left), its scope as wide-ranging and the use of special terms or phrases outside the attendee's mainstream discipline as just acceptable. On the other hand, participants confirmed that only little preliminary knowledge is required to benefit from the course and evidence and lucid examples provided in the course together with the appropriateness of teaching and learning material seemed to enforce the attractiveness of the course for a combined science and engineering oriented population. Moreover, the goal of providing a "Theory-to-Practice" approach has been fully met (Figure 4; right). The assessment of the instructor exhibits very positive ratings, except for the perception of the stimulating style of the instructor's presentation.

In Figure 5 further assessments of the course format and benefits for the attendees are presented, corroborating the modular design of the course and the very high importance of integrating lectures by external guest speakers. Furthermore, 100 percent of the attendees confirmed that they do not need the given references and sources to understand the course content. Concerning benefits for the attendees Figure 5 (right) shows that the goals of the course have been fully met and correspondingly attendees perceived the relevance of the course for their further studies or lives, respectively. The overall assessment of the course (1.8) fits with the fact that 100 percent of the respondents would recommend the course to a colleague. Similarly, after attendance of two course modules also the Chemistry Students' Representation ("Fachschaft Chemie der Studenten", who represents students' interests similar to unions in firms) made the statement that they would recommend the course to chemistry majors.

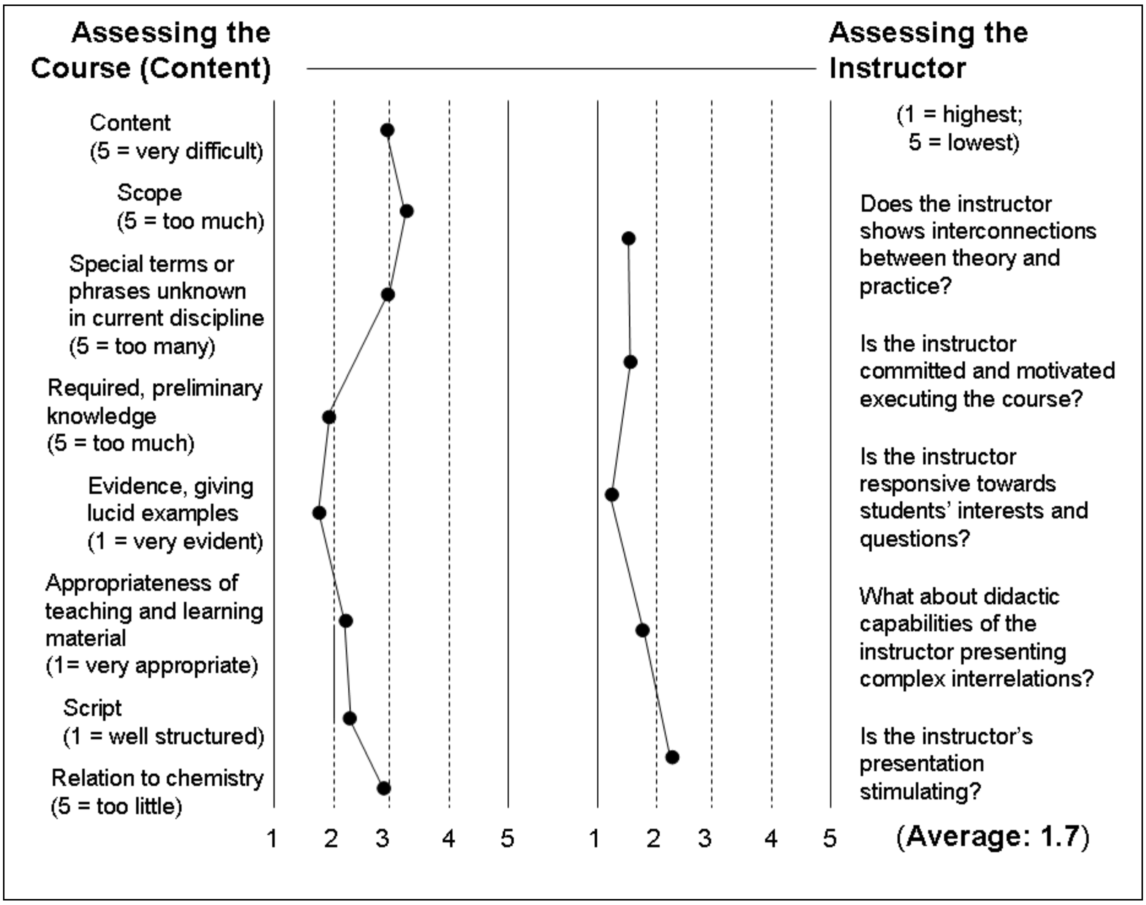

Figure 4: Assessing the Chemical Entrepreneurship course and the instructor.

On the other hand, it must be noted that attendees' options for interactions with course speakers were used little. The instructor's offer to be available for any questions or discussions directly after the lectures has been used rarely by students; also little use was made of the option to address the instructor by e-mail. Hence, there was no indication for the instructor that attendees desire a shift of role of the teacher, from instructor to additionally tutor. Also after their lectures and their Q&A parts the additional meetings with guest speakers (in a restaurant) were visited by only few, usually advanced, course attendees. Currently, it is not clear whether the late ending of the course (19:00) has influenced this behavior.

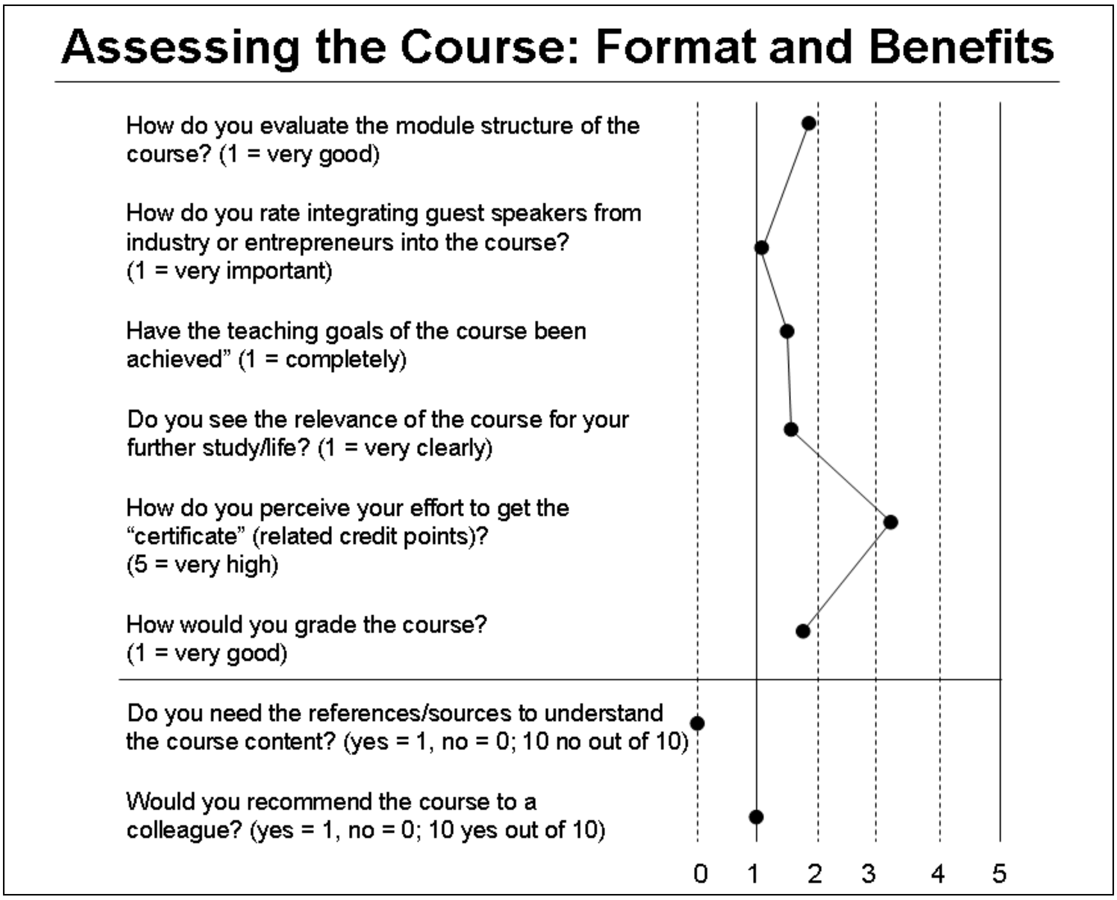

Figure 5: Assessing the course format and benefits for attendees.

5. Conclusions

As a summary, the Chemical Entrepreneurship course has been well received. The pioneered curriculum attracted a broad variety of attendees from scientific and engineering disciplines, age and experience and may serve as a new model for teaching technology entrepreneurship and intrapreneurship in an integrated fashion based on a systems-, process- and intelligence-oriented theoretical framework. Rather than educating "about" entrepreneurship and enterprise the current "Theory-to-Practice" curriculum aims at educating "for" (technology) entrepreneurship including training of "soft" skills, such as presentation skills.

Finally, the extension of the scope of the entrepreneurship curriculum in several dimensions demonstrates how it can be interwoven with business research and practice, in particular, with technology innovation management, research and intelligence and thus can contribute to corresponding areas of research and practice (Davidsson 2002). In this regard, for the chemistry-related fields (chemical) entrepreneurship may be viewed as an intrinsic part of "*Chemical Business* Engineering" [12].

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