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Engineer–Entrepreneur: Combining Technical Knowledge with Entrepreneurship Education—The Israeli Case Study*

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This paper discusses a novel approach taken by the largest engineering college in Israel, Shamoon College of Engineering (SCE), to enhance its students' entrepreneurial intentions and activities. We describe the Engineer–Entrepreneur Program in detail and discuss the contribution of various program modules (the college, students, community, industry and the next generation involvement) to the total entrepreneurial approach of engineering in institutions of higher education. The program has been extremely well received both at the college and beyond, with the government granting it massive support. We found that the entrepreneurial intentions of the students participating in the program were enhanced compare with those of students who didn't participate in the program. Moreover, we found a positive effect of the program on the general grades' average and self-esteem perceptions of the participating students. Despite its uniqueness, the program is applicable in any academic engineering institute, especially in areas with features similar to Israel's.

Keywords: entrepreneurship; education; entrepreneurial intentions; engineering students

1. INTRODUCTION

IN THE NINETEENTH CENTURY, Cardinal John Newman defined the ideal university as being dedicated to the pursuit of knowledge for its own sake. In his view, universities should be the 'high protecting power of all knowledge and science, of fact and principle, of inquiry and discovery, of experiment and speculation.' [1] However, as we look into the twenty-first century, the perception of higher education has changed. The universities are no longer seen only as institutions of higher learning: today's universities are important engines of technological development and economic growth. This includes the ability to apply new technologies, access new markets, develop new products, incorporate optimal management practices in enterprises, and inculcate a high level of skills suited to the entire labor force. The university can substantially contribute to all of these goals, especially at the regional level [1–3]. Technological development in the last twenty years has been described as a veritable revolution, whether in microelectronics, bio- and nanotechnology, materials science, computer science, medicine or other high technology disciplines. At the same time, the boundaries between the engineering disciplines are disappearing as engineering itself becomes more interdisciplinary in order to solve increasingly complex problems [4,5]. The recent economic crises have introduced high risk and uncertainty factors into the business and industrial environments throughout the world.

These technological and environmental changes demand urgent modifications in engineering education to make it applicable to the needs of the twenty-first century. The environment for engineering will continue to undergo significant transformations, driven by global competition in high-tech markets, the outsourcing of production and services, the explosion in the information technology sector, the cross-fertilization among traditional engineering disciplines, and the complicated issues associated with environmental protection and sustainable development [6]. Today, the field of engineering lies in the forefront in the development and marketing of advanced technologies. The ability of engineering institutes to train quality manpower is not enough; their educational programs must be geared to enhancing the students' creativity, original thinking, leading qualities and initiative [2, 7]. In recent years start-up-oriented programs aimed at these goals have been introduced into colleges around the world [5, 8, 9]. While most of these programs are taught in the management and economics departments, an increasing number of start-up programs are now part of the curriculum in the arts, sciences and engineering [2, 7, 10].

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Fostering entrepreneurship is now a matter of the highest priority in public policy. Given the growing concern over technological advances and aggressive global competition, entrepreneurial activities are seen as the driving force of innovation. Consequently, a broad array of programs and services has been implemented to provide a better infrastructure for new ventures. A key element in these activities is the targeting of engineering and natural science students as future entrepreneurs. Graduates of the technical and engineering disciplines (more than graduates of other disciplines) are expected to found companies in dynamic, innovative areas that will generate significant economic growth and boost employment [11, 12].

To date, the new role of higher education has tended to concentrate on describing infrastructural reform and institutional innovation that promote a culture of entrepreneurship within the academic institutions. This includes property development, such as science parks and technopoles [13], industrial liaison offices to support linkage between academia and industry [14–16], and specific university organizations to develop the growth of technology-based spin-off firms. Other aspects deal with entrepreneurial intentions of students in general in non-business areas in particular [11, 17].

Many different types of start-up-oriented programs exist. In general, they are offered to selected populations, and combine practical work with theoretical studies, usually by simulating real world conditions but having the ventures accompanied by a mentor. Despite the large number of such programs in academia, their actual efficacy is in question and their goals often insufficiently clear. The success of most of these programs is measured by the increase of entrepreneurial awareness, the rise in entrepreneurial intention, and changes in perceived desirability and perceived feasibility factors [18–20] even though these variables do not necessarily represent the participants' actual likelihood of success.

Israel has always been considered a vibrant, entrepreneurial state famous for its cutting-edge industry and exportation of high-tech knowledge [21, 22]. It has a relatively large number of patents compared with its per capita income [23]. Its compulsory military service for most citizens is regarded as a levering force that continuously contributes to the development, enhancement, and originality of its economic and industrial sectors [24].

However a different picture emerges in higher education. On the one hand, entrepreneurship is systematically taught in the fields of public policy, economics, business administration and social work; on the other hand, neither theoretical nor applied entrepreneurship education is included in physics, chemistry, pharmacology, engineering, and other technical disciplines. This lacuna may be partially explained by the fact that entrepreneurship training is considered extraneous and dispensable in the sciences and engineering.

Shamoon College of Engineering (SCE), the largest technology college in Israel [23], is located in the south of the country, an area known as the periphery. With a student body of 4000 in 2009, SCE offers engineering programs in six fields. Unlike other institutions of higher education in Israel, SCE believes that the standard admission scores do not accurately reflect the true potential of prospective students. SCE regards the scores as socially, culturally and demographically biased, unfairly limiting accessibility to institutions of higher learning. Therefore it opens its gates to all sectors of the population, providing support and equal opportunity.

Most SCE students come from lower socio-economic brackets, Israel's periphery, or from ethnically, demographically, or gender disadvantaged groups. Twenty-eight percent of the students are women, compared with twenty percent in other Israeli academic institutions, forty-five percent are immigrants, seven percent are non-Jewish minorities, and a very high percentage of the Jewish students are of Oriental origin. [25,26]

We describe a unique, new, start-up-oriented program, the Engineer–Entrepreneur Program, that is being successfully applied at the Shamoon College of Engineering in Israel. The program integrates all the key elements in education and entrepreneurship, as well as other elements that we believe lie at the heart of the program's success. Five critical elements are integrated: community, the next generation, industry, the college, and students—in order to create a comprehensive educational system for academic entrepreneurship. The Engineer–Entrepreneur Program is the only such program that prepares engineers for venture-oriented work in the country's leading organizations and promotes independent start-ups. As stated, the Engineer–Entrepreneur Program can be readily adopted in any academic institution in Israel and abroad.

2. PRESENTATION

The biannual Engineer–Entrepreneur Program includes two academic courses for undergraduates in their third (next to last) year; fourth year students have access to a personal business coach for their final project; and students on the program's individual track can develop independent ventures. The program also affords students the opportunity to gain experience in imparting knowledge to high school pupils and applying their abilities in developing start-ups with them. This project encourages our students to develop ventures aimed at improving the environment and community, operate in close contact with the heads of Israeli industry, and take part in workshops that strengthen the key skills they will need in the global market. This section describes the relevance of each stage in the program.

2.1 Recruitment

Participants in the Engineer–Entrepreneur Program are recruited in a number of ways. Freshmen students are informed about the program through summer mailings and visits by the Entrepreneurship and Innovation Center's faculty to 'Introduction to Engineering' classes in each department. Graduates of the program also bring in new members by word of mouth. Participants are selected on the basis of a written application submitted in the summer prior to the opening of the school year. This enables the program's staff to select participants based on background, interests and experience, and also ensures that a genuine multi-disciplinary environment will be created when students from six different engineering disciplines start working together. The review process and personal interview also allow us to gauge an individual's strength of commitment to a two year program. Students are admitted to the program not by their scholastic achievements alone, but by their motivation to succeed in entrepreneurship in the real world. All of the students at SCE have an equal chance of acceptance to the program as long as their academic standing is up to par and they have completed two-thirds of their degree. Up to now, more that 350 students have participated in the 'Engineer–Entrepreneur' program.

2.2 Team Organization

Participants are divided into permanent teams. Team size may vary, but groups of five to twelve seem to work best. The teams are organized around project themes that the faculty decides; but the students are allowed to express preference for a particular project.

In the introductory meeting, students are given a brief description of the companies and themes and can choose whichever team they want to be in. Company themes usually include the medical instruments industry, Internet, software and hardware, and pharmaceutical and nanotech products. The students and faculty advisor work jointly during the start-up phase to identify potential customers and particular products consistent with the company's theme. Students typically develop a suitable name and logo for their group and theme.

During the second meeting, students begin organizing their team into a business around a corporate theme and start deciding on the product. The organizational structure may vary but the team is encouraged to assign its members leadership responsibilities such as president, records keeper, finance administrator, marketing consultant, R&D analyst, and so forth. We found that teams perform best when each member has responsibility for a specific area of activity. One of the key roles is team coordinator—a student whose only responsibility is to serve as liaison with the faculty. Since most communication goes through electronic mail—it is important that the team also converse with the faculty face to face. The team coordinator generally passes on all faculty correspondence to the team members.

2.3 Faculty

Two faculty members and two senior executives from local industry supervised each team for the entire year. The seriousness of the senior executive's commitment is viewed as affirmation of industry's interest in the program.

2.4 Industry's Involvement

Industry's involvement has been a major factor in the program's success. This subject will be discussed in detail below.

2.5 Team Operation

Class time was often used by the teams to present progress reports of their business planning. We found it most effective to schedule these presentations on a regular basis. All of the teams attended the presentations and added their input in the form of constructive criticism. In this way, the teams gained from the experience of their colleagues.

2.6 Elements of the Program (Fig.1)

The Engineer–Entrepreneur Program is divided into two parts on a semester basis. The first part is based on the course 'Introduction to Management in a High Tech Environment', which introduces students to the complex world of business administration. Students learn how a business organization functions. Each three-hour lecture is devoted to a particular topic. Some topics are conveyed directly, others indirectly. Students gain insights into the fundamentals of marketing, business strategy, organizational behavior and culture, operations and project management, basic financing, accounting law, basic economics and teamwork. Altogether, the courses form a logical continuum that helps the student comprehend the actual workings of an organization. The teams apply their newly-acquired knowledge to organizational situations by analyzing test cases and adopting their mentors' and peers' recommendations. Their conclusions are shared in thirty minute presentations at the end of the semester. Some of the national organizations that were analyzed were Polgat, Teva, Amdocs, and the international organizations included Google, Twitter, EBay, and Intel. Approximately one-third of the program's meetings were headed by senior figures from Israeli industry. Students were required to attend two professional days in organizations, during which they went on guided tours of workshops and offices, sat in on discussions, and witnessed the dilemmas that management has to cope with.

The first part of the program has little to do with entrepreneurship per se, but we found it essential for engineering students without any background in economics and management to learn these subjects. Earlier entrepreneurial programs at the

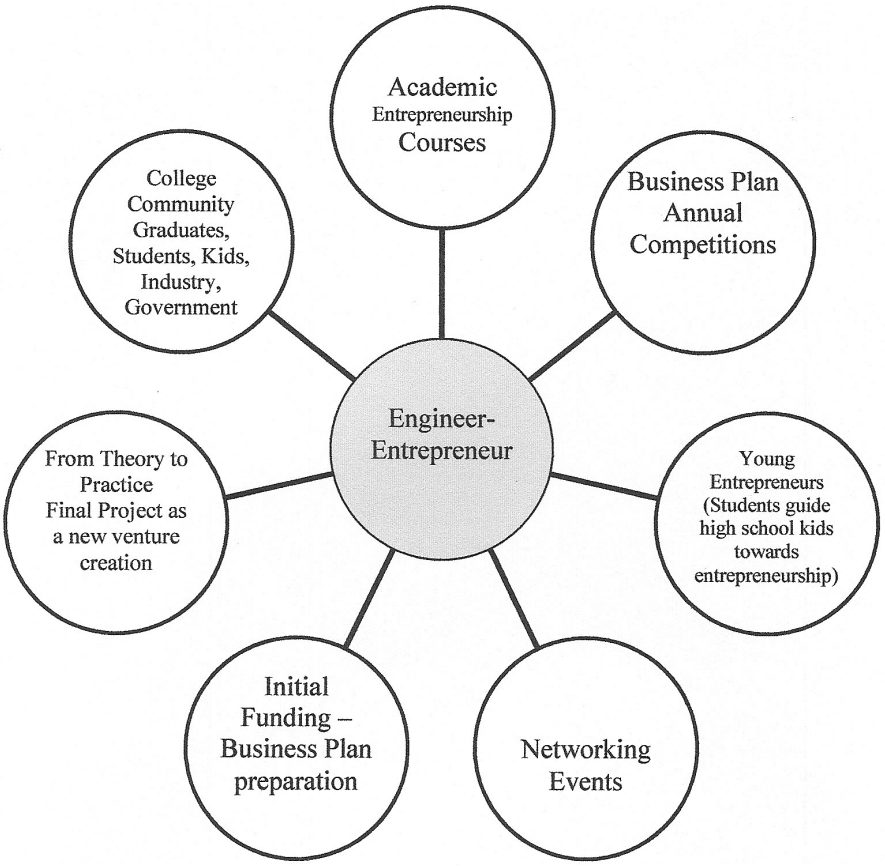

Fig. 1. Engineer–Entrepreneur Program: schematic details. Main stages.

college that ignored basic management instruction faired poorly since they were designed mainly for industrial engineering students who are required to take economics and management courses. We soon realized that success in entrepreneurship remains an elusive goal for an engineering student who lacks this background. Since no textbook was available that contained all of the topics taught in the course, each topic was taken from a different book. For the practical application of theories we generally analyzed case studies according to the Harvard Business Cases style.

In the second semester students take the course 'Business Entrepreneurship' where, in their original teams, they continue to work at putting a technical idea into motion. The course introduces them to the fundamentals of original thinking, intellectual property, business planning, fund raising, developing new products, risk management, and other topics. Here the team members forge ties with leaders in industry, set up prototypes of their product or service, and study the technological and commercial factors involved in idea planning. At this stage they also commence the personal track and develop their own start-ups (see below).

2.7 Grading

The 'Engineer–Entrepreneur' program employs a success-oriented approach to evaluation and grading. Attendance at seminars, student presentations, class meetings and weekly team meetings are compulsory. There are no tests—which is extremely rare in engineering courses. For most students this is the first time they take a course without a final exam. Grading is based on an assessment of how well each participant fulfilled the role that he or she accepted at the start of the semester. The assessment is based on three parameters.

The first part of the grade is a collective evaluation of the group's final presentation and level of teamwork. All the team members are given the same grade. We found that the teams became highly competitive and that a strong correlation existed between a team's level of cooperation and the final grade given by the program staff. Teams that exhibited contention and division generally failed to achieve a high mark in the final presentation.

The second part of the grade is also given collectively and is based on the rating that the general manager of each team gives to the other teams. We explained to the team managers that they could decide whether or not to involve their own team members in their decision, but they had to grade the other teams' accomplishments according to the final presentation. Despite our concern that the grades would be socially biased (influ-

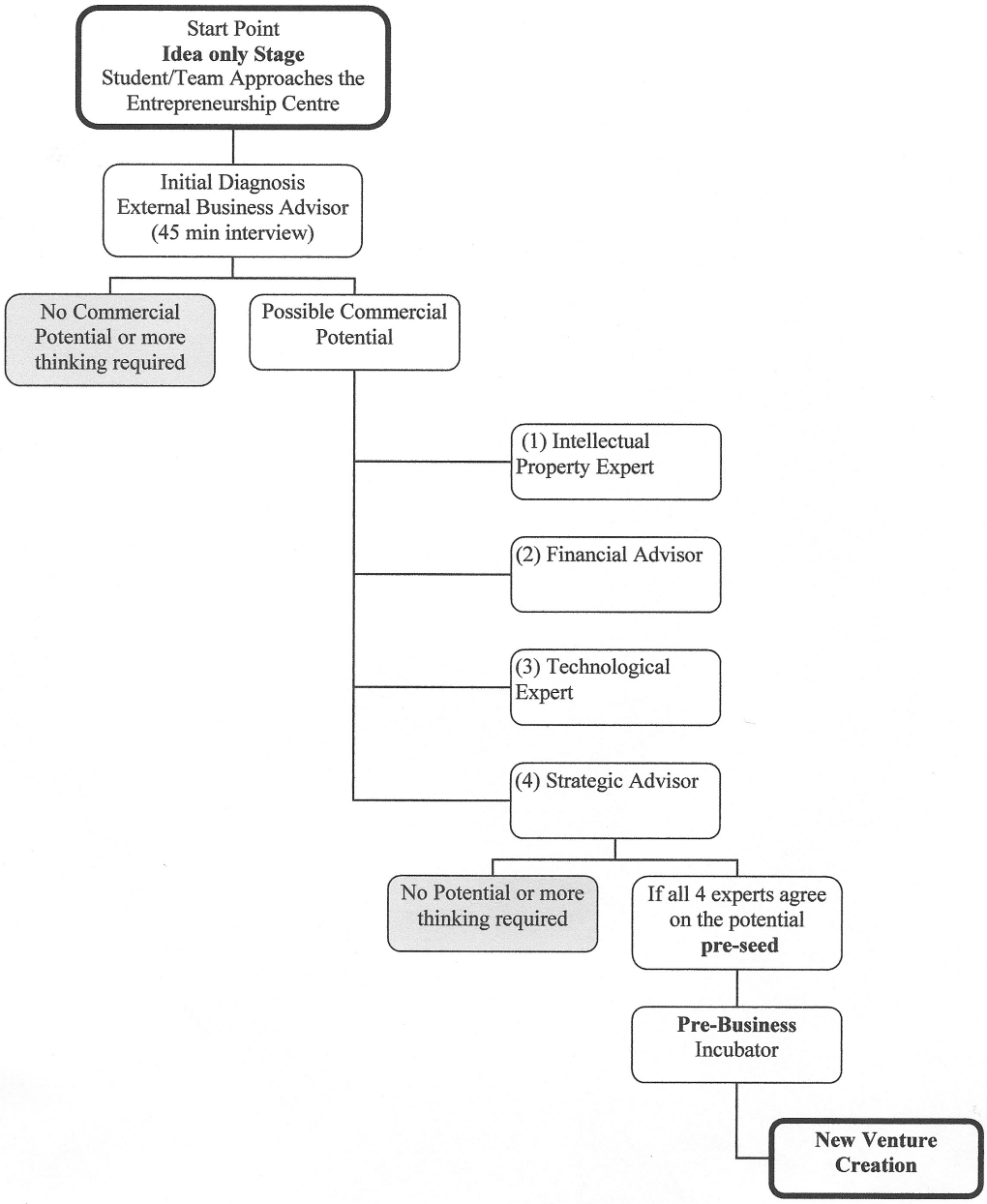

Fig. 2. Engineer–Entrepreneur, an individual model: dealing with a student's start-up idea.

enced by former friendships), we found that a correlation generally existed that was often identical to the staff's grade. (Grades are conveyed discreetly via safe email.)

The third part of the grade is individual and is given anonymously to each team member by members of the same team. At the end of the program all the team members complete a questionnaire that asks them to evaluate their fellow team members according to capability, originality, accessibility, willingness to contribute to the goal, and other parameters. We found that this part of the grade was crucial and often enabled us to identify team members who shirked their responsibilities and let others bear the burden. This type of grading system is quite common in the Israel Defence Forces (IDF) and is used to gain an accurate picture of the relationships inside the teams and add a personal element to the collective grade. The staff's group grade does not always reflect the effort of each team member.

2.8 The Personal Track

The Engineer–Entrepreneur Program is a bona fide academic program. Each course is worth three academic credits, that is, six credits (out of 160) toward a bachelor degree in engineering in Israel. Students work in teams and develop an idea, service or product for commercial implementation. The program also has a personal track in which SCE students and graduates can receive concrete assistance in a variety of fields for their own start-

ups. Students with an original idea come to the program instructors who review the idea and, if it seems feasible, offer assistance for its development. This process is summarized in Fig. 2.

In the first stage, all of the students, as well as the graduates, receive information about the program and personal coaching. The students' requests are sent to staff members via the program's website. Approximately two weeks after the request is received, the student is invited to an initial meeting. In the second stage the staff examine the idea itself and the student's ability to develop it. The student's seriousness and commitment are also assessed. In addition, the idea's novelty, chance of realization, legal strictures and intellectual property rights are weighed. If the student and the idea pass the first stage, the student goes through a series of interviews with experts in various fields: an intellectual property advisor, technological consultant, lawyer, strategic advisor, and financial consultant. The student receives hour-long consultations free of charge to help crystallize the idea and appraise its commercial potential. At each stage, on the advisor's recommendation, the student can halt the process, return to the drawing board and study the initiative in greater depth. Following a series of meetings, the student and idea enter the 'pre-business greenhouse' stage in which the student receives twelve and half percent of the initial outlay plus twenty hours of instruction in commercial writing by national experts. It should be noted that this part of the program is financed and recognized by the government body, The Municipal Centers for the Promotion of Entrepreneurship. During the 'pre-business greenhouse' stage the college protects the student's intellectual property by registering a (generally provisional) patent. Already at this point the student is provided with personal business coaching from a mentor, usually someone on the advisory board. The coaching includes direction, networking for initial fund raising, marketing strategies, and contact with large companies when the project becomes realizable. The coaching may last approximately a year or longer and includes biweekly meetings and regular progress reports. The mentor is recompensed for the time devoted to coaching with 15% of the profits if the venture proves successful.

2.9 Description: the Core of the Program

The Engineer–Entrepreneur Program is a multidisciplinary, integrated program that trains engineers for professional employment in a dynamic, global workplace and promotes the independent ventures of students and graduates. We identified five key elements that are vital to the success of the program and development of the student.

Students in the Engineer–Entrepreneur Program also take part in the Worldwide Junior Achievement organization. They are ardently encouraged to participate in this international organization. The work involves coaching a group of local fourteen–fifteen year olds and helping them develop their own start-up, beginning with creative thinking and culminating in the sale of the product or service. Engineer–Entrepreneur Program students have the opportunity to transfer their knowledge to the next generation and by doing so enhance their own skills in venture development while contributing to the community. At this point it should be recalled that SCE, located in the Israel's southern periphery, is the largest engineering college the country, and the majority of its students are either new immigrants, non-Jewish minorities, or students from low socioeconomic households. That these students are able and willing to return to their former high schools and pass on their knowledge and entrepreneurial skills to the next generation, their academic experience is enriched, synergy between them and the program is created and, of greatest importance, their commitment to the program is reinforced.

Environmental involvement—Participants in the Engineer–Entrepreneur Program are encouraged to develop ventures with social, environmental and green agendas. Such ventures are accorded priority in fund raising, backing, and coaching. When students realize that they are working not only for their own pocket but also for goals that are considered 'moral' and 'laudable', they become infused with greater motivation and commitment to the program. Furthermore, the SCE's focus on environmental and social projects facilitates the recruitment of mentors and senior-level industrialists to the program. The local media's reporting of the college's activism in these areas has a two-fold positive effect: it raises the institute's public image and the program's relevancy in the eyes of the students.

The advisory committee and the involvement of experienced people from business and industry in guidance, coaching, fund raising and networking. We are fully aware of the importance of networking for students from middle and low socioeconomic backgrounds who aspire to success in the business world. The program's advisory committee is made up of approximately fifteen CEOs and assistant managers from various branches: high tech, chemicals, pharmaceuticals, traditional industry and thriving start-ups. They help navigate the program's policy, establish networks for the student entrepreneurs, invite guest lecturers to speak at the college, and arrange visits to Israel's leading plants and organizations. The informal, congenial ties that spring up between committee members and students in the Engineer–Entrepreneur Program benefit both parties. The advisors' connections to industry and academia give the students a head start toward finding their place in the business world. We believe that the involvement of leading figures from business and industry is vital for the program's success and relevancy. Their personal contact can help the students avoid the pitfalls that frequently beset novice entrepreneurs. We encourage senior figures in industry to

join the program by emphasizing the uniqueness of college's geographical location and the opportunity being offered them to contribute to social action. We also encourage their involvement by guaranteeing them a flat 15% of the profits if the start-up takes off.

The college's commitment—Most entrepreneurship programs in institutes of higher learning, especially in engineering and the sciences develop as a local faculty initiative and offer elective courses for undergraduates. The average engineering student can choose electives in Greek history, Renaissance art, or Entrepreneurship. The material in entrepreneurship and management courses in the engineering curriculum parallels the material in secondary elective courses and the students' attitude toward them. We at SCE decided to throw our full support behind the Engineer–Entrepreneur Program and have it serve as the flagship that identifies SCE as an entrepreneurial, innovative, original, socially and environmentally-committed college. In order to back the school's pledge to the program, a number of crucial steps were taken:

All participants receive six academic credits per year, independent of their department or track.

The deans and department heads inform students about the program and encourage registration. They also channel student start-ups of high potential to the program's personal track. The students' schedule is arranged so that the program does not interfere with class hours in other departments.

The college allocated a special area for the program staff to meet with students and hold entrepreneurship-related activities.

The college library is stocked with recently published books and journals on entrepreneurship and relevant Internet sites.

An annual budget has been allocated for conducting a follow-up on the program's performance and research in entrepreneurship education. Also, the SCE has established national and international partnerships with other academic institutes in the field of entrepreneurship education.

Student commitment—The last element is in effect the outgrowth of the first four. It is attained by the careful selection of participants for the program, the creation of personal contact between students, faculty and industrialists (this is achieved through small work teams usually made up of one senior faculty member and fifteen students), and incentives for pursuing the work during the academic year.

3. DISCUSSION AND PROGRAM ASSESSMENT

There is a small but growing body of evidence that entrepreneurship programs add value to students, the degree programs in which they are housed, and the institutions that host them [27]. Kingon and colleagues [28] found 'relatively little published information regarding the efficacy of entrepreneurial programs or courses, especially in the newer programs within engineering.' Indeed, the situation in that field hasn't changed since 2002 [29, 30]. While much has been written recently about engineering entrepreneurship programs, comparatively few investigations provide hard evidence of their success. Several academic papers discussed efficiency and details of entrepreneurship education programs [27, 31, 32]. We examined the program's accomplishments according to a number of short, intermediate and long-term quantitative and qualitative factors and various parameters. (Student grades are discussed separately in another section.) Another test, but one that is not conclusive, is the students' completion of a questionnaire on two key issues: the program staff—a standard questionnaire of twelve closed and two open questions given at the end of the semester, tries to determine the quality of instruction and the course's contribution to the student. The questionnaire is sent through a safe Internet site. (Students are encouraged to take part in the survey by holding a raffle with such prizes as a laptop or GPS.) As shown in Table 1, the average grading on the courses in the Engineer–Entrepreneur program is 5.33 out of 6 comparing with the total 4.54 college average. Moreover, it seems that students are more interested in participating in the evaluation questionnaire on that program compared with the college average (62.5% comparing with 45.6%).

Students in the Engineer–Entrepreneur Program also fill out questionnaires at the beginning and end of the program from which we try to assess their entrepreneurial potential by applying the Ajzen Planned Behavior Theory and Shapero's entrepreneurial event model [33–35]. In particular, we compared by structured questionnaire the perceived desirability and the perceived feasibility of students to start their own new venture before and after participation in the Engineer-Entrepreneur program. The results, as described in Table 2, from the first year (fifty-five students) indicated that on average their entrepreneurial potential and motivation increased significantly (increase of 34%

Table 1. Students' evaluation of the Engineer–Entrepreneur program (2008–2009)

	Average grade (1–6)	% of participation
Engineer–Entrepreneur program	5.33	62.5
Total college average	4.54	45.6

Table 2. Entrepreneurial Intentions of students participating in the Engineer–Entrepreneur Program

	Change in entrepreneurial intentions (%)
Male	+34
Female	+55

for the male students, and of 55% for the female students). The gender difference is partially attributed to the women's initially low inclination toward entrepreneurship, especially women who live and study in a traditionally male-dominated environment such as an engineering college [36–38]. Once the women in the program gained knowledge in entrepreneurship and realized their entrepreneurial potential, a marked rise was observed in their entrepreneurial intentions.

Although the heart of the Engineer–Entrepreneur Program is about acquiring knowledge, skills, and experience in entrepreneurship, we avoid pressuring graduates into launching start-ups or independent companies. The number of companies set up by each class does not necessarily represent the main standard for evaluating the program's success. Providing engineering students with basic skills in management and entrepreneurship is first and foremost the key element for their successful entry and absorption in the workplace. Participation in the program also gives students a competitive edge in the workforce since most engineering graduates in Israel do not take courses in business and organization disciplines. The program also stresses 'intrapreneurship' as an inseparable part of entrepreneurship. Some of the effects of the Engineer–Entrepreneur and other entrepreneurship education programs may not be immediately evident. The hope is that students who participate in those programs will come away with knowledge and skills that may influence their future career decisions. In order to best evaluate the entrepreneurship education program, assessment must take place several years after the students enter the real workplace.

The program's qualitative parameters were also appraised: the number of articles on the course that appeared in the local media, the number of SCE graduates who expressed interest in taking part, the number of academic associates in the program, and interest in the program by leaders of the business community. About 25% of all articles published in local media that mentioned the SCE different activities during the first year of the Engineer–Entrepreneur program were about the different programs' activities, and more that 50 leading managers in the Israeli High Tech Industry voluntary joined in the programs' activities. The Ministry of Commerce and Industry's contribution to the program puts the stamp of national recognition of the project's relevancy. Government participation goes hand in hand with Israel's policy of channeling capital to the development of the geographic and socioeconomic periphery of the state.

4. CONCLUSIONS

The Engineer–Entrepreneur Program at SCE reflects a marked change from the regular educational paradigm. We believe that the program can be implemented in any academic engineering institute. It readily lends itself to multi-disciplinary teams and encourages students to develop and market their original ideas.

The Engineer–Entrepreneur Program has succeeded in conveying the managerial and entrepreneurial side of the engineering profession, areas that are not systematically taught in engineering colleges. The program enhances the students' proficiency in leadership, teamwork, and original thinking, and provides them with a wide range of skills that are indispensable for survival in the rapidly-changing, global workplace of the twenty-first century. Students gain first-hand experience in establishing and managing a start-up—from the birth of an idea, through its growth, to its realization and ongoing development.

The program is especially suited for fringe populations and regions with socioeconomic and cultural gaps because the development of a student's abilities, skills, and business acumen tends to narrow and remove these gaps. A new horizon appears before the graduates as they discover that social mobility is open to them. Engineering, as taught in most institutions, does not prepare the student for organizational life and contemporary organizational development. This lacuna is an often insurmountable obstacle especially in the weaker sectors of society that lack the knowledge and self-confidence to set up a business network and obtain initial funding for a start-up.

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