The need for improvement in innovativeness development and entrepreneurship training in high school and university science education

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Overview

It is the intention of educators to provide students with knowledge and skills needed for their future careers. The curriculum in high school and university science courses are designed to provide students with the key concepts in science to fuel their understanding of the world around them. In addition, the curriculum aims to develop broadly applicable skills such as problem solving, critical thinking, and communication, such that students are prepared for the workplace at the end of their schooling. While this intended curriculum would prepare students to become productive members of society, its delivery tends to fall short of realizing the aims and goals of the official documents. Science teachers have a propensity to emphasize the detailed examination of theoretical phenomena and performance of laboratories with explicit directions and expected outcomes. While these skills might be of great benefit to a small number of students that remain in academia or otherwise enter a specialized scientific field, the majority of students suffer. Whether the purpose is to produce scientifically literate citizens or to produce scientists and engineers specialized for research and development, an education in science ought to equip students with more than knowledge of scientific facts and rote completion of cookbook laboratory exercises. In particular, it ought to provide students with the ability to be innovative and self-sustaining in the world economy through an understanding of science and its applications in the context of the rest of society.

Currently, there is a disconnection between learning in the classroom and using that knowledge once school is completed. It is unfortunate that this is so, because science education offers a unique opportunity to teachers for the development of transferable skills. In exploring scientific concepts, the minds of students can be challenged to problem solve, find patterns and innovate. Innovativeness is a key skill that must be developed in every student, in order for him
or her to succeed in today’s society, regardless of future path. For example, in science-related careers, researchers must propose novel study topics and designs, engineers must plan novel products to develop or improve, and doctors and pharmacologists must think up novel treatment options for patients. In careers outside of science, employers in all fields are seeking innovative young minds to fill their company positions, as tiresome and repetitive desk and labour jobs that once dominated the economy have been outsourced or automated (Wallis and Steptoe, 2006). Providing an education that fosters innovative thinkers will be of benefit to the students once they leave the school system, while simultaneously benefiting employers and ultimately the global economy, as innovation drives economic growth (Gates, 2007). It is becoming widely recognized that vital to our economy is the need to equip young people to clearly identify and handle problems as well as yield creative and practical solutions to real world problems (Hartshorn and Hannon, 2005).

A key category in the workforce that has been absent from the reasoning outlined thus far is that of entrepreneurism. This generation of young people have been raised in a society that not only encourages entrepreneurship, but has also fostered both ambition and pragmatism (National Association for the Self-Employed, 2004). Entrepreneurship has become a mainstream career option for many of our young people, more so than ever in the past (National Association for the Self-Employed, 2004). Since the science curriculum aims to prepare students for future careers, entrepreneurship training ought to be integral in this discipline, or at least made readily available. Currently, a student of science education is not exposed to entrepreneurship training unless they opt to enrol in business courses as well. Even with this exposure, the two disciplines remain isolated from one another, and this is inadequate for students to develop an understanding of the place of science in the context of society and how the discipline can be made applicable in an
independent business venture. It is particularly relevant to science education, since the
c characteristics of a science student intersect with those of entrepreneurs, as outlined by the
Consortium for Entrepreneurship Education (2003). These include being achievement-oriented,
self-motivated, resourceful, independent and industrious (Consortium for Entrepreneurship
Education, 2003). While there is debate about whether entrepreneurs are born or made, and
subsequently, whether entrepreneurship can be taught (Henry et al., 2005), it is the position of
the author that regardless of personality, students can be trained in entrepreneurship and given
the knowledge and skills necessary to make them competitive in any pursuit of this nature.
Moreover, not only can this be done, but must, as it is vital to the individual success of science
students as well as the economic growth of the nation and global market. Lastly, the skills of an
entrepreneur are also widely applicable to other areas of the job market, such that a student
trained in entrepreneurship would demonstrate enhanced performance as an employee as well as
in an independent venture, making exposure to entrepreneurial skills all the more essential.

Current practices

High schools and universities are not completely without training in innovation and
entrepreneurship in science courses. In general, there are avenues, through extracurricular
activities and special programs, for providing this type of training, which are currently in practice
and are effective means of expanding on scientific knowledge and skills. Unfortunately, to a
large extent, these have not been integrated into the curriculum and are generally not offered to
more than a select few students. The ensuing paragraphs will examine the nature of a few such
programs.

Extracurricular activities have provided advanced science students with the opportunity
to exercise their creativity and expand their entrepreneurial abilities. Unless the activities are run
as a part of the required education program, it is most often only more dedicated and proficient science students that will engage in these experiences. Often these types of programs are directed toward gifted or otherwise distinctive students in order to supplement their regular course-work. Examples of extracurricular activities involving innovation in science include the Destination Imagination competition, Lemelson MIT InvenTeams and the Greater Toronto Sanofi Aventis Biotechnology Challenge, to name a few. Destination ImagiNation is creativity and problem solving organization that hosts annual process-based problem solving competitions for groups of students across the continent (Destination ImagiNation, Inc., 2005). The Lemelson MIT InvenTeams program is a research grant aimed at encouraging invention in high school students (Lemelson MIT Program, 2005). The GTA Sanofi Aventis Biotech Challenge is a contest encouraging students to propose a project to solve a problem using knowledge of biological systems, and its intent is to establish mentorship with the local biotechnology community (Sanofi-Aventis Biotech Challenge, 2007). There are also opportunities in the form of research grants provided at the university level, such as the Innovation Challenge Awards offered by the Natural Sciences and Engineering Research Council of Canada (2004) and the Youth Science and Technology Outreach Program offered by the Ministry of Research and Innovation (Government of Ontario, 2006). Although these and many similar initiatives focused on promoting creativity and invention in high school and university-level students are excellent programs, they exist outside of the curriculum or course content of science education. Thus, the bulk of students educated in science have no exposure to these or similar opportunities for creativity and innovativeness in the current education system.

There are a few specialized programs that integrate innovation and entrepreneurship into the curriculum in high school and university. Students in high school may have the opportunity
to participate in Junior Achievement programs, which have links to the curriculum and focus on
deploying skills in business to the classroom (Junior Achievement of Canada, 2007). At the
university and postgraduate level, students may opt to major in programs that relate science and
business in various forms, including biotechnology, industrial engineering, or the Master’s of
management and innovation offered at the University of Toronto, for instance. More specialized
and rigorous programs have been implemented and studied around the globe. For example,
Queensland University of Technology in Australia has found remarkable success with their
newly created Bachelor of Biotechnology Innovation program, which trains biotechnology
students in entrepreneurship at the undergraduate level so effectively that graduates are pursued
above biotechnology students possessing both PhDs and MBAs (Collet and Wyatt, 2005). The
program experiences such success because it addresses the need highlighted by industry to both
maintain technical expertise as well as incorporate skills in product development,
commercialization of research and other areas of business (Collet and Wyatt, 2005). In another
example, the University of Nevada in the United States has incorporated all phases of product
development into projects for senior electrical and mechanical engineering courses, and has also
administered an accelerated version of the courses in local high schools (Wang and Kleppe,
2001). It is evident that the need for innovation and entrepreneurship education in science
courses has been recognized and some progress has been made in integrating training into more
traditional science curriculum, and these initiatives have met with great success.

The incorporation of innovation and entrepreneurship into education of any discipline is
the goal of many national and regional foundations and organizations. Organizations such as the
Innovation Network (www.thinksmart.com) and Creative Programs of Ontario
(www.creativeprograms.ca) promote creativity in education. Other organizations, such as the
National Foundation for Teaching Entrepreneurship (www.nfte.com), the Consortium for Entrepreneurship Education (www.entre-ed.org), and the Young Entrepreneurs Association (www.yea.ca), support entrepreneurship education and efforts of educators to incorporate entrepreneurship into school curriculums. The initiatives described here indicate that innovation and entrepreneurship training are somewhat accessible to certain science students. However, much more integration between the disciplines can be achieved. With extensive resources and expertise, innovation and entrepreneurship organizations have the potential to collaborate with high schools and universities in initiating the evolution of a scientific education system in which innovation and entrepreneurship training are deeply embedded.

**Recommended practices**

Science education ought to offer the skills and background knowledge to produce self-sufficient, innovative thinkers capable of generating solutions to issues facing society. Besides technical or theoretical knowledge in science, successful graduates ought to be equipped with skills, attributes and behaviours that will make them productive in the workforce. These include behaviours such as acting independently, coping with uncertainty, risk-taking and opportunity seeking, skills such as problem solving, innovativeness, planning and persuasiveness, and attributes such as self-confidence, versatility and resourcefulness (Hartshorn and Hannon, 2005). Other portable skills graduates ought to have developed from education include written and oral communication, teamwork and critical thinking (Henry et al., 2005). The skills, behaviours and attributes outlined here are amenable to development from the study of entrepreneurship, particularly when taking an innovative approach in creating practical solutions to real world problems. Development of these skills can only occur if training in entrepreneurship is more thoroughly engrained into the everyday curriculum of science programs. The programs described
above that incorporate innovation and entrepreneurship into science education are impressive and highly effective, however, the scale of most projects and their degree of specialization are beyond the capacity of the typical high school or university classroom. Instead, proposed here are practical recommendations applicable to science curriculum at all levels. The focus is on developing portable skills that can transfer to the workplace or self-employment and fostering an environment amenable to creative idea generation.

The skill that is fundamental to the training of entrepreneurs is innovation. An education based on developing innovativeness would provide preparation for both the workplace or for self-employment that is well beyond what is currently achieved (Hartshorn and Hannon, 2005). Since the goal is to promote creativity, forward thinking and a free flow of ideas, education must extend well beyond the chalkboard. The most effective method of developing innovativeness is through the use of project and problem-based learning. By posing problems to students, based on issues in the real world, students can develop effective problem solving and critical thinking skills, as well as begin to exercise creativity when generating solutions. An emphasis must be placed on learning by doing (Hartshorn and Hannon, 2005). Projects can span multiple disciplines such that science becomes applicable to the outside world, and involve group work to exercise communication and interpersonal skills. This is valuable since the majority of innovation occurs in teams, and frequently involves the union of unrelated fields (Wallis and Steptoe, 2006). Projects and problems need not be complicated or differ greatly from the established curriculum. Students can be asked to develop novel uses for a magnet or investigate potential materials for thermal insulation in buildings, clothing, coffee cups, and so forth, which are simple projects that stem directly from topics currently covered in the curriculum. Furthermore, by integrating business into problems and projects whenever possible, the basics of
economics and developing business strategies can be taught in order to produce solutions that are practical and therefore of potential use to the targeted populations. Innovation is the driving force behind entrepreneurship training.

Another widely proclaimed method of incorporating creativity into the curriculum is through the use of free design of laboratory experiments. There is considerable debate about this method since misbehaviour or an absence of guidance can be counterproductive during the laboratory session, giving rise to what is commonly referred to as cookbook labs, which have explicit directions and demand achievement of idealized outcomes (McNeal et al., 1998). However, several methods of involving students in experimental design have been successfully implemented in high school and university science labs (McNeal et al., 1998). These laboratories combine the right amount of direction and freedom to allow students to constructively contribute to the experiment’s design, either by providing the opportunity for students to choose the topics and protocols through research in the primary literature, or by collectively brainstorming the methods by which they will investigate a certain question proposed by the instructor. In all cases, the emphasis is on innovation, but a more structured laboratory session prior to the inquiry-based session is included to introduce students to the methods and materials. These approaches have been documented with surprising success, and it is believed that the key to success is to prime students with the background exposure that will allow students to be comfortable directing the remainder of their experience (McNeal et al., 1998). Since the use of laboratories is already extensive in high school and university science courses, labs are an ideal opportunity for students to demonstrate their creativity in addressing problems and develop related skills such as critical thinking when assessing the validity of their solutions and communication when presenting findings.
Not all aspects of the science curriculum are amenable to a hands-on or problem-based approach, but that does not imply that these aspects cannot be adapted to include the development of the relevant skills and attitudes toward innovativeness and entrepreneurship. In every aspect of teaching, an atmosphere in which it is safe to take risks and think laterally ought to be cultured. If this atmosphere is successfully attained, it will become self-generative. Once students feel comfortable with making mistakes and learning from their mistakes, questioning the information put before them and inquiring about alternative ways of resolving a problem, innovativeness and inventiveness will emanate from the classroom. However, this atmosphere can only be created if students are able to learn by example. This means that teachers must be innovative in order for students to be innovative. Teachers must regularly involve techniques that promote creative thought, such as brainstorming, design, and mind mapping. They must also encourage the development of the main concepts in science, instead of the inconsequential details, such that students have a conceptual toolkit of generative ideas on which to build. A unique and interesting technique from the Innovation Network (2004) can be adapted for education, which can be referred to as the alien view. When employing this technique, thought processes are reversed, such that instead of attempting to classify or define objects and phenomena, one considers how the object or phenomenon would appear to an alien that had never experienced such a thing beforehand. This is another opportunity to expand one’s perspective, and promote the generation of novel and alternative ideas, uses, or solutions in everyday life.

The recommended practices outlined here are meant to lay the foundation for innovation and entrepreneurship training in high school and university science courses. To recap, it is recommended that science education be adapted to include project and problem-based learning,
incorporating an interdisciplinary and interactive approach to problem solving, in order to stimulate innovativeness. Business and entrepreneurship training is also encouraged in order to prepare students for the workplace or for self-employment. Additionally, an innovative approach to teaching is recommended for all aspects of science education, with the incorporation of creativity-inducing techniques and the development of an atmosphere that stimulates a constant flow of ideas. Undoubtedly, an innovative education that challenges students, one that is more applicable and engaging to the student, will facilitate the acquisition of knowledge as well as skill development. Promoting innovativeness and entrepreneurship in science education would aid learning during schooling and, more importantly, equip students for their future careers.

Summary

Training in entrepreneurship is necessary for advancement in the knowledge-based economy of the global market. The present teaching strategies used in North American schools do not adequately prepare students of science who will enter the workforce after graduation. Whether destined to work in academia, in industry, in an unrelated field or as an entrepreneur, science students would benefit from the development of portable skills and expansion of their inventiveness throughout their scientific education. Science students ought also to be exposed to the areas of business relevant to the commercialization of research, in order to connect science to the context of society. Skills such as problem solving, critical thinking and communication, which are critical to innovation and entrepreneurship, can be developed in the classroom in the context of science and transferred to the workplace. The preparation of science students to become both innovative and entrepreneurial is of direct benefit to both individual learners and society as a whole, and thus, science education should be designed to place students where, with proper training, they are capable of thriving – at the forefront of innovation and entrepreneurship.
References


