Triple-Helix of NTNU-Industry-Municipality: A New Dynamics of Knowledge Construction and Competence Development

Fan Yihong,
Visiting Professor of PLU/NTNU; Professor, Institute of Education Research, Xiamen University China, Email: fanyihong2003@yahoo.com
Eirik Refsdal,
NTNU, FLL and NTNU Open Organizer, eirik@refsdal.no

Abstract: Using the Triple-Helix relationship of university-industry-government as a model this paper seeks to analyze the new dynamics between university, company and municipal government in promoting knowledge construction and competence building. Specific cases of the FIRS LEGO League Tournament in Trondheim in the fall of 2005 and NTNU Open at NTNU in the spring of 2006, Summer School of 2001 and 2002, as well as the Intelligent House Project in collaboration with SIMENS and Malvik College are presented and analyzed to inspect the changing dynamics of cross-boundary cooperation between NTNU, various industrial companies and the Municipal government in setting up new environment for young people to acquire knowledge, foster creativity, gain real-world working experiences, improve operational competence, cultivate team spirit, and stimulate their zest for science and technology.

Key Words: Triple-Helix dynamics; cross-boundary cooperation; knowledge construction and competence development

Introduction

The Lisbon Strategy set in March 2000 called for economic, social and environmental renewal and sustainability of EU, with innovation as the motor of economic change, building learning society as the long-term guarantee, and education and training as the central focus for reform. The ultimate goal of the Lisbon Strategy is for EU to develop by 2010 to “become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion[1].” Then, the Stockholm European Council of March 2001 implemented three strategic goals for education and training systems, stressing on quality, access and openness to the wider world[2]. Next, In March 2002, the Barcelona

[1] “Education & Training 2010" The Success of the Lisbon Strategy Hinges on Urgent Reforms, Council and Commission Joint interim report on the implementation of the detailed work programme on the follow-up of the objectives of education and training systems in Europe. COM (2003) 685 of 10 February 2004(doc. 5941/04).
[2] “Education” Council report to the European Council on the “concrete future objectives of education and training systems” (doc. 5980/01) http://register.consilium.eu.int/pdf/en/01/st05/05980f1.pdf

European Council approved the program of work to implement these goals[3], and called for closer co-operation in the fields of higher education and vocational training. The work program constitutes the strategic reference framework for the development of education and training policies at the Community level in order to make education and training systems in Europe "a world reference for quality by 2010".

Against this background, most universities in Europe engaged themselves in vigorous reform and start to form new relationship or to strengthen the existing relationship with industry, public entities and the government. How to understand the new transformative initiatives among various forces? Loet Leydesdorff and Henry Etzkowitz developed a Triple Helix model for analyzing the university-industry-government relationship and dynamics. Using this Triple Helix Model, this paper examines some innovative programs carried out at the Norwegian University of Science and Technology (NTNU) to analyze the relationship and dynamics of NTNU, local and international industry and the municipal government.
The programs studied are the FIRST LEGO League contests (2000-2005), Summer School (2001-2002), Physics Track (2004-2006), and the Intelligent House Project (2004-present). After the study of these cross-boundary collaborative programs in and beyond NTNU, this paper concludes that the Triple Helix dynamics propels the innovative and creative education and training programs at NTNU and the local communities.

Context: The Need for More Innovative Science Education

According to *EUROSCENE 2003: The Norwegian Project Report* prepared by the Norwegian Ministry of Education and Research, the Norwegian educational system has been undergoing constant reform on science education in order to stimulate more young people to study scientific subjects – which in turn will increase their chances of choosing a career in science and technology (EUROSCENE Report 2003).

[3] Detailed work programme on the follow-up of the objectives of education and training systems in Europe (OJ C 142 of 14.6.2002) http://ue.eu.int/newsroom/related.asp?BID=75&GRP=4280&LANG=1

The report points out that there were not enough candidates choosing to study scientific subjects at the tertiary level and even in grade 13 there was significant decline in the percentage of students who chose to study physics, chemistry and biology (EUROSCENE Report 2003: 21). We can see specific statistics from Table 1 listed by the report, which is included below. These findings have placed an acute challenge for education at all levels in Norway to engage students in innovative ways to approach science and technology, so that young people will develop both competence and a desire to study scientific subjects in college. Under these circumstances – and in order to compensate for the limited classroom teaching and learning of science – various non-formal science education activities and programs have been designed targeted at different levels and scope of studies.

Table 1: Number of students in upper secondary school who chose to study physics, chemistry, and/or biology and have passed the courses[4].

	2002[5]	**2003[6]**
Physics, grade 12	5517 (9,9 %)	5312 (9,5 %)
Physics, grade 13	2942 (6,9 %)	2850 (5,9 %)
Chemistry, grade 12	3917 (7,0 %)	3887 (6,9 %)
Chemistry, grade 13	2469 (5,8 %)	2521 (5,2 %)
Biology, grade 12	4397 (7,9 %)	4005 (7,1 %)
Biology, grade 13	2620 (6,1 %)	2512 (5,2 %)
Total number of students[7], grade 12	55987	56173
Total number of students, grade 13	42762	48456

[4] The numbers of students does not include students who have prepared for examinations at an unauthorized school or privately, ørfor students who failed the course.
[5] Number of science students in the table for 2002 are given by Statistics Norway (www.ls.no / statistikk / tabeller / karakterer i videregående skole / nasjonalt fra NVB)
[6] Number of science students in the table for 2003 are given by Statistics Norway, http://www.ls.no/stati/karv/03/java/nasjonen.html
7 Number of students in class 12 and 13 in 2002 and 2003 is given by Statistics Norway, http://statbank.ssb.no/statistikkbanken/

Source: *EUROSCENE 2003: The Norwegian Project Report*, (p. 21)

The EUROSCENE 2003 Report lists 24 such projects carried out all over Norway, that fall in 9 categories, namely, festivals, events, competitions, science centers and museums, recourse centers, science clubs, projects, camps, organizations and foundations (EUROSCENE Report 2003:32). FIRST LEGO League is one of the programs that fall in the competition category, while The Physics Track, the Summer School and the Intelligent House project were carried out as specially designed projects to stimulate students' interests in specific areas of natural science study.

The paper will explain how the various NTNU related programs have been trying to engage different entities on and off campus to stimulate young people's interests in scientific subjects and practice, as well as innovative and creative ways of carrying out these projects. By employing the Triple Helix model, this study also analyzes the significance of the relationship of university-industry-government and the dynamics this relationship has to promote innovative educational and training programs.

The Triple Helix Model of University-Industry-Government Relationship

Most of us know the Double-Helix structure of DNA that proposed by James Watson and Francis Crick in 1953 that led to the Nobel Prize for them in 1970. Few of us, though, aware the Triple Helix model for understanding the dynamics of university-industry-government relationships proposed by Henry Etzkowits and Loet Leydesdorff (Etzkowitz & Leydesdorff, 1995). The advantages in using this model to study the relationship of University-Industry-Government, according to Leydesdorff, lies in that it is possible to study the relationship in transition and to pay attention to different configurations of the relationships. Since this model allows complexity, it can depict the chaotic and emerging mode of change in the relationship and dynamics. It can also detect the self-organizing mode of the dynamics. Since network relationship is paramount in knowledge-based economy, this Triple Helix model becomes a useful instrument to understand the changing relationships of

University-Industry-Government. For the visual model please see Figure 1.

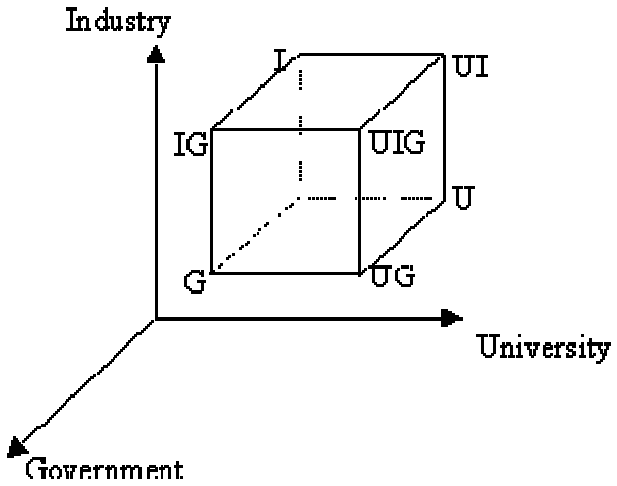


Figure 1 The three-dimensions of measurement in a Triple Helix configuration and their combinations (source: Loet Leydesdorff, *Scientometrics*, forthcoming)

As Leydesdorff explained, "The mutual information in the three dimensions of the Triple Helix enables us to measure networks at each moment in time in terms of probability distributions and to evaluate the measurement results in terms of the dynamics. Unlike co-variation, correlation or co-occurrence measurements, the mutual information is defined in the case of interactions among three dimensions. However, the mutual information in three dimensions can no longer be considered as a similarity measure. It informs us about the size and the sign of the probabilistic entropy generated by the interactions within the complex system (Leydesdorff, Ibid). "

Thus, it's convenient to use the Triple Helix model to analyze the innovative programs among NTNU, the industrial companies and the municipal government to understand the dynamics of the relationships in promoting changes in education and training to meet the need of the constituencies.

The NTNU Collaborative Programs

FIRST LEGO League

Background Information about FIRST

The American inventor Dean Kamen started FIRST (For Inspiration and Recognition

of Science and Technology) wanting to inspire kids to become scientists. One of his ideas was the LEGO robotics tournament FIRST LEGO League (FLL). The first significantly scaled FLL tournament was held in the U.S. in 1998 and involved 200 teams. By 2005 the number of teams had risen to more than 7500 and competitions were held in more than 30 countries all over the world. The founder's vision was "to create a world where science and technology are celebrated……where young people dream of becoming science and technology heroes…"

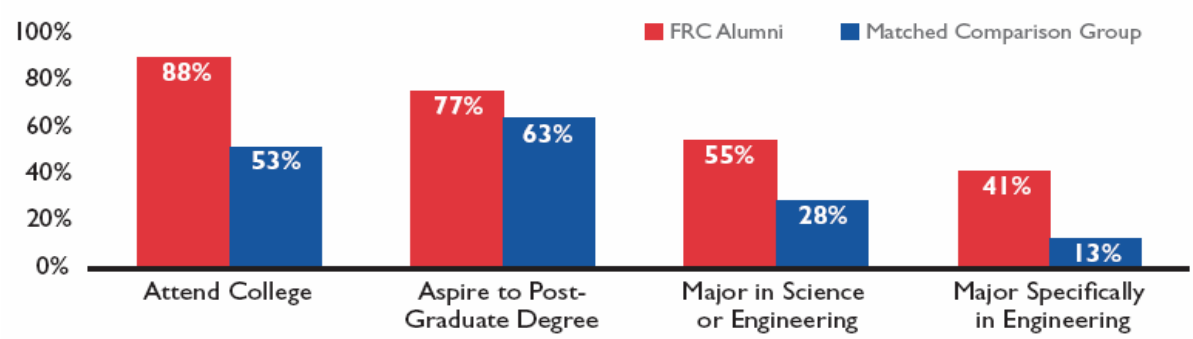
Thomas Freidman who writes *The World Is Flat* takes a very critical view toward the school education saying that: "The American education system… just is not stimulating enough for young people to want to go into science, math, and engineering." (Freidman 2005:270). So Kamen seeks out to find different ways of engaging young people in scientific study and technological experiences. He initiated four different kinds of FIRST activities addressing young people of different grades to achieve new kind of science and technology endeavor through designing, building, programming and operating robots to accomplish challenging tasks related to real world scientific and technology tasks. FIRST LEGO League is only one of the four level activities. Each year there is a new theme for the challenge, but the fundamental tasks and requirements stay the same. Students who have taken part in this FIRST Worldwide Tournaments have truly gained interest in science and technology, built up stronger self-confidence and team work capacity and have become more adequately literate from a technological viewpoint.

In 2004 Brandeis University conducted an evaluation of the previous FIRST programs and found the following results:

Education in Science & Technology

- *FIRST* Students vs. Comparison Group
- Seek education in science and technology
- Twice as likely to major in science or engineering
- More than three times as likely to major specifically in engineering

Table 2: Comparison between FIRST Students vs. Comparison Group



Source: *Brandeis University, Center for Youth and Communities, Heller School for Social Policy and Management, 2004 (as cited in FIRST 2005 Report).*

From Table 2 we can clearly see that after having a FIRST experience, there is significant growth in the percentage of students who attend college, which is 35 percentage points higher than the comparison group; students who go on to post-graduate degree increases by 15 percentage points; those who major in scientific subjects increased by 27 percentage points, almost the double of the comparison group; and the students majoring specifically in engineering almost doubled.

Without any doubt, the result demonstrates the success of the FIRST programs. In the following section we'll take a look at how the FIRST LEGO League has been implemented in Norway and in Scandinavia.

FIRST LEGO League in Norway and Scandinavia

In Norway, schools, colleges and universities are not the only ones that care about education and how it develops. Municipal government and large companies also play an important role in promoting innovative ways of carrying out education. In September 2000, a foundation called FIRST Scandinavia was established at Statoil's Research Centre in Trondheim, loosely based on Dean Kamen's FIRST initiative. The reason for this was a realization among several Scandinavian enterprises, governmental bodies and organizations for scientists that within few years there would be a shortage of skilled labor with scientific and technological competence. If

this trend was to be turned, children would have to be offered the possibility to experience fun and technological projects already at young age. And just as important, the projects needed to be such that the children themselves would be the driving force of the experience. The best way to learn is by doing, and getting to do things that are fun makes the learning much easier.

FIRST Scandinavia has gone on to build up organizations of volunteers in more than 30 cities all over Scandinavia, where the FIRST LEGO League tournament is held every year. In every city the tournament is a collaborative effort of volunteers, the local municipality, the local university, technological companies and so on. I.e. in Trondheim, Tekna (the organization of scientists), NTNU (the university), Trondheim municipal, SINTEF (a scientific research institute) and several technological companies like Statoil, Rambøll, Trondheim Energiverk, Powel, Siemens and Cowi are all involved in making sure that several hundred children aged 10-16 years can experience the fun of technology through the eight weeks the competition lasts every year.

2006 will be the sixth year of organized FIRST LEGO League tournaments in Scandinavia, and a total of 5000 kids are expected to participate in a total of 31 cities in Norway, Denmark, Sweden, Iceland, Faroe Islands and Greenland.

FIRST Lego League 2005: Ocean Odyssey

The theme for FIRST LEGO League 2005 was Ocean Odyssey, offering the participants an opportunity to explore the ocean, the largest part of our planet earth and the least explored areas of our world. Each team had to choose a specific topic as a research project. The mission of the 2005 FLL challenge was to take action to ensure a healthy, diverse and productive ocean environment. The participating teams should recognize that the ocean takes up more than 70% of the earth's surface, yet only 1% of the water has been studied (FLL 2005 Challenge Brochure). So we have a long way to go in studying our ocean and its vital role in regulating our natural environment on our

planet.

The teams were supposed to dive deeper into the ocean to collect data through web resources, find problems that affect the ocean environment and build and program a robot to creatively solve the problems, in a fun team atmosphere. They were also supposed to use technology and creative thinking to solve the technical problems and be able to present their solutions to the FLL theoretical and technical judges. The missions for the robot to accomplish in the Ocean Odyssey were as follows: to set free a dolphin; to place an artificial reef; to do responsible fishing; to prevent pollution; to recover valuables; to locate a sunken ship and to repair an underwater pipeline. All these tasks are similar to the real life tasks you might meet with if you are involved with underwater operations in the ocean, and using their robot the teams had to solve them within two and a half minutes.

The FLL teams have from April to September to apply, and then the technical and theoretical challenges are released in September. All teams then get the so-called Challenge Set, containing the LEGO parts needed to build the robot competition area, as well as access to on-line resources for instructions. But if you thought FLL was only a robot competition, you have totally missed the point. Actually the tournament includes four main parts, a theoretical presentation, a technical presentation, a talent show and the robot contest itself. During the process of preparing for the tournament, each group is also required to write a diary, in which they can keep record of their work, research, team building process, problems they encounter and achievements they make. They also need to work in teams, and need to use a lot of on-line and computerized resources. They have mentors, coaches and parents who are constantly working with them. It is such an integrated and encompassing activity that the participants all enjoyed the whole process no matter what age group they belong.

Physics Track

"Fysikkløypa" Physics Track

The Institute for Physics, the Institute for Electronics and Telecommunications and the School Laboratory at NTNU and Trondheim Science Center organized a program called "Fysikkløypa" Physics Track to invite sixth graders to come to NTNU to experience all kinds of physics experiment. When the sixth graders come to NTNU, they will be presented about 10 quiz-questions. The pupils need to run around NTNU's various laboratories to investigate about 30 experiments in order to find the answers to the 10 quiz-questions.

The first edition of " Fysikkløypa" was arranged last year (winter of 2005), so it was only the second edition we had this year. Professor Berit Kjeldstad and Associate Professor Per Morten Kind at the Department of Physics, NTNU initiated the project They collaborated with Assistant Professor Nils Kristian Rossing at PLU/Skolelaboratoriet (Department of Teacher Education and Science Laboratory), NTNU. For 2006, the project included cooperation with the Department of Electronics and Telecommunications, NTNU, in order to have a wider range of experiments and demonstrations. In particular, the addition of a soldering experiment
proved to be very successful. For 2007, the project will be as it is for this year.

Fysikkløypa 2006

Last year, the pupil-group went through 32 activities in 3.5 hours, including experiments with air, water, sound, light, electricity and magnetism. The purpose of Physics Track is to put their curiosity to the test, and the reason for this is to make them wonder how the world around them actually works in order to make them more interested in natural science. 14 physics students from NTNU also participate in the Physics Track, acting as guides/supervisors for the children.

In 2006, more than 1150 sixth graders from the two Trøndelag counties will participate in the PT (Physics Track), which is about 20% of all sixth graders in the two counties. The Institute for Physics sent out invitations last year, and expected to get about 300-400 children coming for the event. They got about 1200 instead, and

had to prolong the National Physics Week from one week to three. This new way of science education to children greatly stimulated the interests and motivation of children in science study and work.

Feedbacks of Fysikkløypa 2006

This program generated very positive feedback from the pupils. At the end of every day, we handed out a small questionnaire for the pupils to fill in. They were asked to list the three experiments that they liked the most, and in addition, make a comment on whatever they may want to say about Fysikkløypa. By browsing through these comments, we find that the kids were very happy with the whole program, and some even stated that they had learned a lot during the day - and these comments were totally voluntary. One of the pupils said that Fysikkløypa had made her aware of what mathematics could be useful for. Judging from the pupils' feedbacks, it is well justified to say Fysikkløypa succeeded in raising the pupils interest in science.

Feedback from the school teachers has also been very positive. Many teachers have told us that there are too few possibilities for them to organize anything similar to Fysikkløypa at their own school. The teachers see right away that their pupils are very excited with these kinds of hands-on tasks, and that the benefit of learning is large. Therefore they would really want to copy Fysikkløypa's way of engaging the kids. As a matter of fact, one of Trondheim's upper secondary schools (collage (Byåsen videregående skole)) have used Fysikkløypa as inspiration to arrange a similar project in which they invite kids from local junior high schools to come over and perform science experiments.

Summer School "Strawberry and Chocolate" (Sommerskolen 2001 and 2002)

This Summer School program was sponsored by Norsk Hydro and initiated and carried out by the staff at the *Centre for Science and Technology Teacher Education* (Skolelaboratoriet for matematikk, naturfag og teknologi) in collaboration with *The Plant Biocenter* (Biological Institute), *Dept. of Energy and Process Engineering,*

Department of Biotechnology, *Nidar Company* (one of the largest chocolate companies in Norway) and the *Science Center* of Trondheim. Both Summer Schools, invited 20 pupils, 10 male and 10 female students, who had just finished their 9th grade, to take part in this one-week experiential program. The students were all recruited from schools near Trondheim. The program was focusing on the process of making chocolate with dried strawberries.

On the first day, the pupils went to The Plant Biocenter picking different kinds of strawberries; bringing them back to the laboratory to study their quality and taste, as well as the factors influencing their growth. They also did DNA studies and analysis of the strawberries. On the second day, they went to the Dept. of Energy and Process Engineering to learn more about drying and freezing techniques using equipment and facilities at the department. They used the strawberries they picked the day before, freezing and drying them to examine the changes and to experience the process. At the end of the second day they used fluid nitrogen making ice-cream.

On the third day, the pupils went to Nidar Chocolate Company to make chocolate including the strawberries they picked and dried the days before. They also experimented adding different flavors to the chocolate and strawberry mixture. They were also invited to inspect the complete process of making chocolates at Nidar. This visit in the chocolate factory was probably the climax of the week.

On the forth day, they returned to The Plant Biocenter to do further DNA-analysis and using, among other things, chromatograph to analyze the composition of different flavors. They were also solving a crime mystery using DNA analysis. In this way, they were able to use the knowledge and understanding they have just obtained, as well as their imagination and their verbal and organizing skills.

On the last day, they went back to the Gløshaugen campus of NTNU to carry out more experiments with food, making cheese, butter and jelly. They were also testing how

well they could separate between very thin solutions of saltiness, sweetness, bitterness and sourness. The pupils need to taste each of them to tell whether they are sweet, sour, salty, or bitter. Sometimes the difference was very small. This exercise was preparing them for the task to be a part of a taste panel, evaluating the quality of the chocolate they made earlier in the week.

This is a typical case where the industrial company sponsored the student experiential learning for the purpose of stimulating students' interests in natural science studies and preparing them for their willingness to chose science as their career. Some teacher were also joining the student groups some of the days during the week.

The evaluation of the week was very good, both from the students and the teachers. If it is possible to raise money, NTNU will try to develop new Summer Schools with different subject, for example *Energy for the future, Build and equip modern houses* or *Space Technology*.

Analysis of the Programs Using the Triple Helix Model

According to Leydesdorff and Etzkowitz, using the Triple Helix model serve several unusual functions in studying social and organizational relationships and dynamics:

1) It can be considered as a "multi-structural/ multi-functional" framework in contrast to the structural-functionalist model in which a single function was expected to be carried by a single institution;

2) How institutions and functions operate in relation to each other could then become the focus of a research program;

3) Functions and institutions can be considered both as constructed and as reconstructed in the light of socio-cognitive developments in scientific paradigms, fields, and specialties;

4) The focus on the emerging interdiscipline of science, technology, and innovation thus shifted from structural to action and change parameters.

5) Communicative actions generate codes of communication over time (in order to reduce the uncertainty). These codes of communication can feed back as selective structures on the generation processes, both recursively and interactively.

6) While the agencies at the nodes are active and recursively selective according to their own specific functions and institutional constraints, the network system of university-industry-government relations adds a layer of distributed, uncoordinated, and therefore uncertain interactions.

7) The various representations interact and operate on each other in the transaction spaces between institutions and functions at the network level, but with different (sub)dynamics for the various partners involved.

--Summarized from Leydesdorff and Etzkowitz 2001

By employing this model when we analyze the NTNU programs we realize that there are quite an interwoven dynamics between the university and industry, industry and municipal government, as well as the relationship among NTNU, industrial companies and the municipal government, as well as with local schools. For example, we interviewed the FIRST Scandinavia leader from Statoil Company, she said that she made efforts trying to get support from the municipal government in promoting the FLL in Trondheim and in Scandinavia. She talked with the mayor, brought persons from the government entities to the FLL Tournament so they would be able to see the value of the program and in turn to offer support to it. She also invited the NTNU professors to act as referees and judges so to attract student participants. In the end the event and activity became a multi-structural and multi-functioning event serving multiple purposes, not only providing the students with higher-tech skills through FLL activities, but also offering them the chance to carry out team project, to communicate with peers, parents, advisors, coaches as well as counterparts in other regions and countries. As next step, the organizers of FLL are going to acquire more support from local authorities to implement FLL into the school curriculum.

Examining the FLL case against the Triple Helix model, we can see that in this relationship, the representatives of the industrial company have been playing a more important role in promoting this innovative way of learning for young people. They take the initiatives, by persuading municipal leaders to give support, by inviting NTNU professors to participate, and by rallying more companies and public entities as Tekna and Union with Engineers to support the event. When schools in themselves lack the motivation for innovative programs, it is the industrial companies that gave them a push. In this way, the entrepreneurial attitude plays an important role in the whole organization of the program. Now the NTNU started the NTNU Open to make it more

related to the university employees and students, the dynamics may change. And if they succeed in embedding FLL into the school curriculum, there may be even more changed dynamics, since schools are going to play a stronger role in this learning event. Thus the Triple Helix relationship and dynamics of NTNU-Industry-Government concerning FLL is in flux and always changing. Nevertheless, as we have a clear view of the Triple Helix relationship, we'll know that it helps the young people to have innovative and creative learning experiences. Therefore, they are more ready to take on science and technology field of studies and better equipped for knowledge-based economy.

On the similar token, when we examine the Physics Track program, we will see that that program was very well designed. But it is more happened on NTNU campus, with not as much involvement of industry as the FLL programs have been. When we observe the Summer School Strawberry and Chocolate program, we'll see it has a close collaboration between NTNU and the local company and sponsored by the national company. But we can easily discover that it does not have much of the municipal government's role in it. So we can make a suggestion to the municipal government that if they give some support, this program can be kept running.

Conclusion

The Lisbon 2004 report clearly calls for innovative and cross-curricular programs to attract young people's interests in learning science and technology, especially by promoting entrepreneurial attitude and creativity skills. It also advocates partnerships at all levels including local, sectoral, regional, and national. In this way different entities can share responsibility, develop full involvement of all partners (institutional, the social partners, learners, teachers, civil society, etc.) in the development of education and training systems which are flexible, effective and open to their environment. Using the Triple Helix model we have seen certain NTNU related programs demonstrate very strong multi-structural multi-functioning relationships and

dynamics of NTNU-Industry-Municipality, while other programs display a stronger involvement between NTNU and industry, but with less government involvement. Other program shows a very strong engagement between NTNU and local schools. From this analysis we understand more about the dynamics and future developmental possibilities of the innovative programs. Triple Helix is a very complicated and powerful model that can serve different layers of analysis. This paper is just at the beginning stage to explore the use of this model. When time allows, this study can be carried deeper and wider.

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