Project Title: Education in Nanotechnologies (EduNano)

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NEED ANALYSIS REPORT

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Introduction

The Nano Centers of five leading Israeli research universities in conjunction with three European universities are developing online courses within the framework of an EU funded TEMPUS project - Education in Nanotechnologies (EduNano).The courses will target MSc degree Israeli students, industry professionals and high school teachers.

A short survey was distributed to the Nano companies and to the nano researchers in order to meet the industry employment needs and the needs of academic researchers in the field of Nano technologies and help to provide future students with the most relevant skills and competencies in this field.

This report identifies and analyses the skills and competences needed for the nano industry in the next 2-5 years.

Background

The project aims to develop online nanotechnology courses that will be used in the partners' MSc degree programs and teacher training. Each course will be designed by the best laboratory/department in the field which disposes with the necessary infrastructure and facilities. They will develop e-learning courses and record lectures and practical work in clean rooms in nanotechnologies.

The project objectives are:

- To design syllabi and course content and assessment for regular and continuing education courses in nanotechnologies to meet the user needs and to determine the credits for each course unit, based on ECTS.

- To select innovative content for the defined learning outcomes and video record lectures and practical work in the high-tech laboratories of partner institutions.

- To adapt/develop new e-learning courses with modular structure for the innovated curricula of partner universities and to establish a platform and procedures for knowledge sharing inside Israeli academy, industry and students.

- To perform a pilot test and to start the implementation of the joint modules/courses.

The preliminary need analysis at the early stage of the project was done in order to analyze the nano industry training needs and accordingly adapt/develop new e-learning courses.

Need Analysis objective:

Analyze the nano industry's employment and training needs in order to provide future students, teachers and industry professionals the most relevant skills and competencies in this field.

Methodology:

1. Learning outcomes table of the various courses was uploaded to Google Docs and filled by the EduNano partners.
2. A short survey was designed in order to analyze the nano industry training needs. The survey included: 36 learning outcomes of 14 courses designed by 8 academic institutions and one company.
3. The Israel Venture Capital (IVC) database and INNI's Nano firm dataset were used for the preparation of an inventory of Israeli Nano companies.
4. The survey was distributed via Opinio (on-line survey tool) to 140 Nano companies CTO's or managers.
   The Edunano partners were asked to distribute the survey among Nano companies that used their institutions infrastructures and to their nano center researchers.

Limitations:

The well-known problem with questionnaires is the non-responsiveness/low response rate. To overcome it, we sent several reminders and asked personally people to fill in the questionnaire.

Survey results

We have collected 33 answers. This is a reasonable score considering the short delay available for this analysis in order to start the courses adaption/ development as soon as possible and in the time frame of the project.

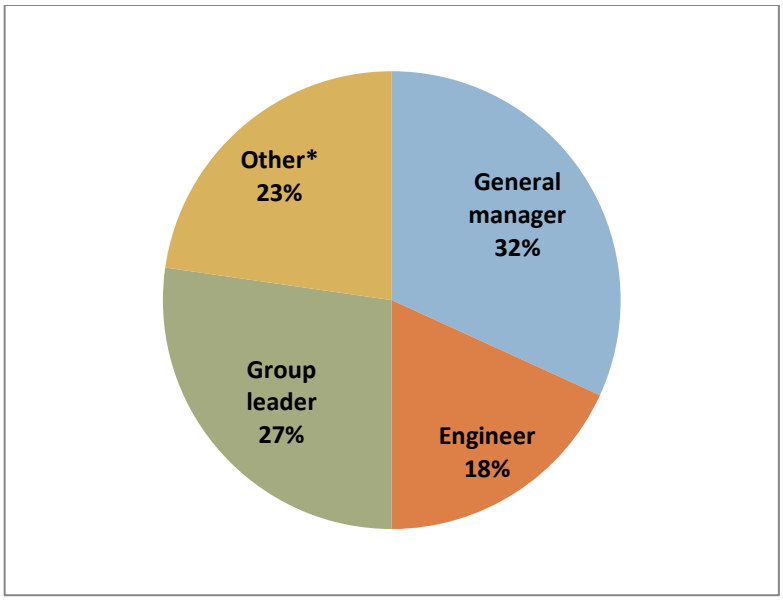
Analysis of the companies that responded to the survey

Company/ Institute:

22 respondents (65%) are from Israeli companies.

Current position of the industry respondents: Figure 1 shows the main current positions of the respondents from the industry.

Figure 1- Current position of the industry survey respondents (n=22)



*Other: R&D group area manager, chairman of board, project manager, CTO and senior company VP for engineering and technological excellence

About 60% of the industry respondents (10) are group leaders or general managers, 23% (5) has other managerial positions and 18% (4) are engineers.

12 respondents (35%) are from academic institutes. 6 of them are from Israeli institutes (Tel-Aviv University, Technion, Hebrew university and Weizmann institute of science). One of them is the head of INNI (Israel National Nanotechnology Initiative), One is the head of an academy nano center and oneis industry liason.

The other 6 are from academic institute abroad (Technical University of Sofia, Istituto Italiano di Tecnologia, Italy and Budapest University of Technology and Economics). 4 of them are researchers and 2 Post docs.

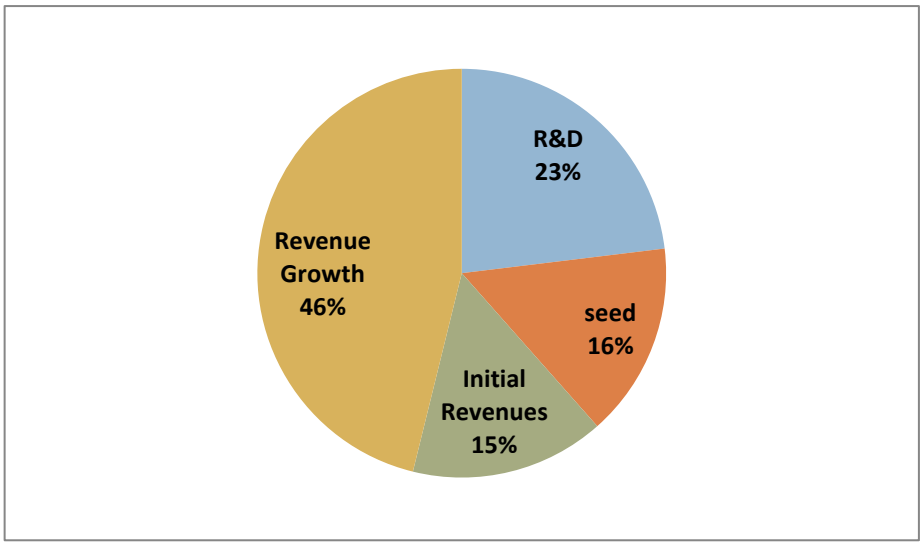
The results of this survey represent mainly the opinion of companies' senior managers and academic institute researchers.

The 22 respondents from the industry are working in 19 different companies.

Below are some data regarding these companies.

Company stage: Most of the companies that responded to the survey are at their revenue stage.

Figure 2- Company stage (n=13)

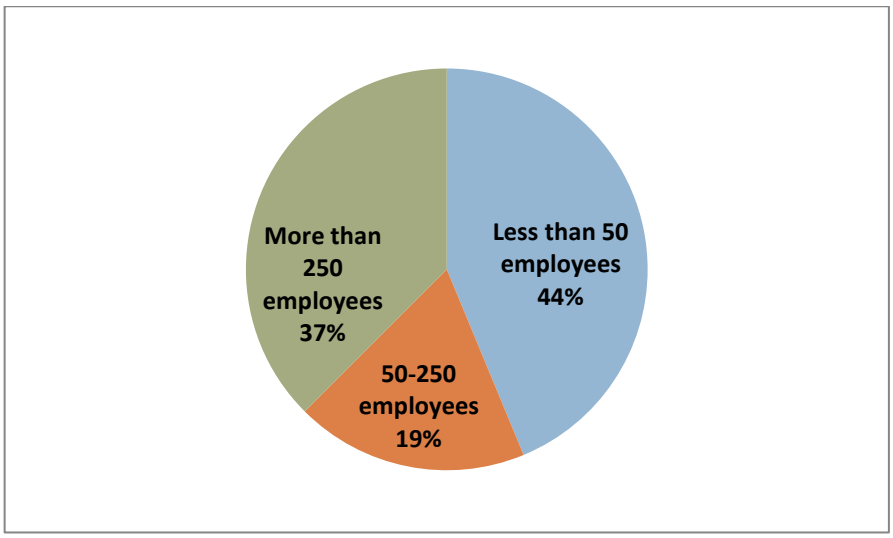


Companies classification: Most of the companies (10 out of 17) are classified in IVC as Miscellaneous Technologies: Industrial Technologies, Nanotechnology or defense.

Year of establishment: 10 companies are well established companies that were founded between the years 1937–1998, 5 companies were established/founded between 2001-2007 and five companies were established/founded after 2010 (n=16).

Number of employees: 7 companies (44%) are small companies with less than 50 employees. 3 companies employ 50-250 employees (37%), and 6 companies (19%) are large companies - with more than 250 employees (n=17).

Figure 3- No. of Employees (n=16)



Skills and competences that are needed for the industry

The next tables present the interest/need of the survey respondents in the different skills and competences according to the following metrics:

- Very low 1
- Low 2
- Average 3
- High 4
- Mandatory 5
- Not relevant to my field of expertise 0

Table 1 - Weizmann Institute of Science courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Scanning Probe Microscopy- Principles, Theory and Applications	Analyze and Understand the results of selected characterization methods: AFM, STM, TEM, SEM, XRD, XPS	31	10%	13%	77%	9%
	Predict the effect of various scanning parameters in Scanning Probe Microscopy	30	37%	23%	40%	12%
	Identify analytical techniques in your work and in the work of others in Scanning Probe Microscopy	30	20%	37%	43%	12%
	Decide which of the various modalities of Scanning Probe Microscopy are appropriate for a specific sample/scientific question	31	19%	42%	39%	9%
	Suggest potential applications of SPM in practical and industrial environments	29	24%	34%	41%	15%
	Propose standard SPM experiments for solving a scientific or technical problem	29	21%	26%	52%	15%
	Perform basic image manipulation and analysis procedures (leveling, filtering, histogram adjustment, statistical and gain analysis) on SPM images	27	19%	33%	48%	21%

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Table 2 - Ben Gurion University of the Negev courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Nano medicine and target drug delivery: where are we going?	Know the fundamentals of nano science in general and nano medicine in particular	26	8%	38%	54%	18%
	Understand the principles and motivation for target drug delivery	21	29%	33%	38%	35%
	Familiarity with the tools that are used for Nano medicine studies	22	27%	36%	36%	32%

Table 3 - Bar Ilan University courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Nano Science and Nano technology why is "nano" different and how is it useful?	Fundamentals of nano science – Theory and applications	31	3%	18%	84%	6%
	Electronics of nanodevices and particles	13	0%	54%	46%	7%
	Optics of nanodevices and particles	13	0%	36%	64%	0%
	Chemistry of nanodevices and particles	13	0%	43%	57%	0%
Kinetics of materials	Fundamentals of sold state diffusion in nano materials and nano devices	32	19%	34%	47%	6%
	Diffusion based experimental methods in nano Technology	13	29%	29%	42%	0%

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Table 4 - The Hebrew University of Jerusalem courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Macroscopic quantum coherence in engineered nano systems	Understand the advantages and disadvantages of different engineered quantum nano systems	32	19%	25%	56%	6%
	Calculate basic properties of different quantized nano systems and estimate sensitivity to noise and measurements	31	35%	39%	26%	6%
Nanotechnology in Service of Humanity	Know and understand the operation principles, advantages and limitations of important experimental techniques in the field of nano science	34	9%	21%	70%	0%

Table 5 - Tel Aviv University courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Introduction to Surface Science	Familiarity with basic surface science concepts	30	0%	23%	77%	12%
Atomistic Simulation of Materials	Understand the capabilities and limitations of different computer simulation methods to learn about the properties of materials	31	13%	39%	48%	9%
	Know how to access state of the art simulation codes that are freely available for the study of molecules and solids (know how to install them in a computer and know how to run them in parallel computers)	31	35%	32%	32%	9%
	Study the properties of materials by doing computer simulations of the interactions between their atoms	30	37%	33%	33%	9%

Table 6 - Elbit courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Advanced materials and nanotechnologies for electrochemical Energy Storage Systems	Fundamentals of Electrochemistry	32	13%	28%	59%	6%
	Materials selection for Electrochemical Energy Storage	30	20%	30%	50%	12%
	Storage mechanisms, Materials Design, Operation Mode and performance Evaluation of Energy Storage Devices	29	21%	31%	48%	15%

Table 7 - Technical University of Sofia courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Design of Nanoscale MOS IC's	Highly specialized knowledge on CMOS integrated circuit layout, basic technology, IC design and modeling and specific physical effects in short channel transistors	29	24%	28%	48%	15%
Nanomaterials for electronics	Advanced knowledge of a field of materials for nano electronics and their use in nano devices fabrication	32	6%	19%	75%	6%

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Table 8 - Polito courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Bio Nano electronic devices for biosensing	Basics of quantum mechanics useful for the design and use of nano devices in particular nano sensors	30	20%	37%	43%	12%
	Knowledge of the possible device production techniques of nano systems in particular nanogap realization	30	13%	37%	50%	12%
Micro interfaces for contacting the Nano World	Design of CMOS Circuits for the management of ReadOut interfaces	28	36%	25%	39%	18%
	The use of CMOS Technology and post processing processes for the implantation of integrated sensors	29	28%	28%	44%	15%
Molecular electronics for the realization of novel nanoelectronic devices	Basics on quantum mechanics and of the use of molecules, in particular organic ones for the realization of electronic devices	13	24%	38%	38%	7%

Table 9 - G-INP courses skills and competencies

Course name	Courses skills and competences	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Nanostructure analysis	Overview of the fundamentals of Scanning Probe Microscopy (SPM based nanolithography: STM, AFM, Near field optics) and of their place in the present development of nano science and nanotechnology	30	17%	13%	70%	12%
Bio technologies	Global overview of bioelectronics sciences and technologies	27	22%	19%	60%	21%
	Study of Bioelectrical interfaces with the dual goal of monitoring physiological phenomena or biological species an of interacting with biological functions	24	29%	33%	38%	29%

Conclusions from the analysis

- The courses which are planned to be developed cover wide and different spectrum of competencies.
- All the proposed courses skills and competencies are considered to fulfill average or high or mandatory need.
- Almost all the courses competencies and skills are relevant to the companies and academy that respond to the survey.
- The skills and competencies which were rated by more than 70% of the respondents as high need or mandatory are:
    - Analyze and understand the results of selected characterization methods: AFM, STM, TEM, SEM, XRD, XPS
    - Introduction to Surface Science
    - Advanced knowledge of a field of materials for nano electronics and their use in nano devices fabrication
    - Overview of the fundamentals of Scanning Probe Microscopy (SPM based nanolithography: STM, AFM, Near field optics) and of their place in the present development of nano science and nanotechnology
    - Know and understand the operation principles, advantages and limitations of important experimental techniques in the field of nano science

Most of these courses are introduction or overview skills.

In addition, question 5 in the survey included an additional course to which the respondents were asked to rank the "Training and Hands on skills" needed for the industry in the next 2-5 years.

Table 10 presents the need that the survey respondents attributed to the course training and hands on skills.

- Almost all the 'training and hands on skills' were rated 'high or mandatory'.
- The Hands on skills of this course are relevant to at least 80% of the companies.

The courses developers will take into consideration all the needs that were given by the respondents to the courses skills and competencies.

Table 10 - Additional course of Tel Aviv University (Simulation of Microelectro mechanical System (MEMS) Devices) **– Training and Hands on skills**

Course name	Training and Hands on skills	N	Low or very low	Average	High or Mandatory	Not relevant to my field of expertise
Simulation of Microelectromechanical System (MEMS) Devices	Photolithography with positive tone and image reversal resists	27	11%	22%	67%	21%
	E-Beam evaporation	27	7%	33%	59%	21%
	Deposition of PECVD silicon dioxide	26	8%	23%	69%	24%
	Reactive ion etching (RIE) of silicon dioxide	28	7%	32%	61%	15%
	Deep reactive ion etching (DRIE) of silicon	26	7%	37%	56%	15%
	Chip singulation – wafer cleaving	25	24%	36%	40%	26%
	Chip singulation – wafer cleaving	25	20%	24%	56%	21%
	Critical point drying (CPD)	24	25%	29%	46%	29%
	Profilometry (step height characterization for photoresist, silicon dioxide, metal, etc.)	28	11%	21%	68%	15%
	Ellipsometry (thickness measurement of PECVD silicon dioxide	30	10%	27%	63%	9%

	Confocal microscopy (depth measurement of silicon after DRIE)	30	7%	27%	66%	9%
	Wafer cleaning and photoresist stripping	26	12%	27%	61%	24%
	Atomistic computer simulation of materials	28	32%	29%	39%	18%

Additional Knowledge fields that were not covered by the courses skills and competences mentioned in the survey

The respondents were asked to specify knowledge fields, that will be needed in the nanotechnology industry in the near future (next five years), which were not covered by the courses skills and competences mentioned in the survey.

The respondents answers /additional knowledge fields are presented below:

- Nanophotonics
- Bio-nano interface basic and fundamental principles.
- Various spectroscopies: Raman, IR, fluorescence. Electron microscopy for nanomaterials. Plasmonics.
- Introduction on the serious challenges which are facing CMOS devices (and nanotechnology), for example: 1) Leakage, variations, interconnects, 2) Device density limited by power dissipation, 3) CMOS are going to operate near ultimate limits (no transistor can be fundamentally better), Solutions: low power design techniques, improve design efficiency, increased performance by even higher integration (of slower transistors). 4) The promise of (bottom-up) nanoelectronics: a) Understanding devices at the molecular scale, b) New tools for metrology, c) New materials, d) Unit processes for directed self-assembly, e) New devices for new applications, f) New architectures for ultra-dense systems, g) Terascale electronics.

- Silicon Photonics, more focus on nanoparticles.
- Epitaxy, selective growth.
- CMOS fabrication and monitoring, even of a mature process like 1um, and introduce the students = new Eng to the real world.
- Immobilization techniques for biosensors; Cathode and RF sputtering; Growing and deposition of silicon dioxide; GaAs technology; Basic MEMS technology.
- Thermal properties of nanomaterials.
- The use of CAD software for non-mechanical engineers.
- Machine materials for stiffness and low immunity for vibration. composite materials, ultra clean with high damping. nano positioning at high throughput settling to 1 nanometer in miliseconds.
- Industries which are users of nanotechnology (and not developers and producers) will have to understand the potential,the capabilities and limitations of nano technology.