Educational Needs and Open Education Resources in Micro- and Nanotechnology

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***Abstract*—To keep up with the rapid development within micro- and nanotechnology, and to cover the wide range of specialized topics, there is a need for higher education institutions to collaborate and to share knowledge to give the students the competences and skills that the industry requires. The NanoEl project aims to share courses between European and Asian higher education institutions, in total 11 partners, through open education resources. The paper reports on results from three surveys targeting the industry needs for competence, the universities' need for and motivation to use open education resources and students' desires and interests in utilizing open education resources within micro- and nanotechnology. The results provide valuable insights and input to the development of the open educational courses in the NanoEl project.**

Keywords—micro- and nanotechnology, open education resources, engineering

I. INTRODUCTION

In the last decades, micro- and nanotechnology have had a great impact on markets and industries and is expected to continue to revolutionize in the years to come. Study programmes in these technologies are now available in many universities worldwide [1]. However, there is a major challenge for a university to cover all aspects of this rapidly developing technology, and universities tend to specialize in certain areas of micro- and nanotechnologies, as well as micro- and nanoelectronics. To keep up with the rapid development, and to cover the wide range of specialized topics, there is a need for higher education institutions to collaborate and to share knowledge to give the students the competences and skills that the industry requires [2], [3]. NanoEl is a project under the frame of Erasmus+ Competence Building in Higher Education. The project aims to transfer knowledge between European and Asian higher education institutions, in total 11 partners. The European partners are universities in Bulgaria, Italy and Norway, the Asian partners are universities in China, Malaysia, India and Israel [4]. By sharing knowledge, the partner institutions' master programmes within micro- and nanotechnology is to be renewed and modernized. In particular, the programme aims for sharing courses, implemented as open education resources (OERs). For the institutions involved, the education offerings within the field of study will thus be considerably broader than what the individual universities in itself is capable of. Through NanoEl, courses at MSc level will be made available and thus facilitating virtual mobility of students and teachers/ researchers. In this paper we will report results from the mapping of 1) the industry needs for competence within micro- and nanotechnology, 2) the universities' need for and motivation to use OERs in micro- and nanotechnology and 3) students' desires and interests in utilizing OERs.

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II. THE SURVEYS

In the project three different surveys were prepared, targeting the industry, the academic staff at universities and students. Questback, which is an online survey and feedback software system, was used as the mapping platform for all three surveys.

A. Survey for Industry

The survey for the industry was mainly targeting companies in the partner countries in China, India, Malaysia and Israel. First, the respondents were inquired about his/her position, the number of employees in the company and the business category. Subsequently, we asked two main questions. First, on a long term (more than 3 years) point of view, what are the needs for your company in specific domains? Secondly, on a long term (more than 3 years) point of view, how many employees does your company need to hire or to be trained within specific domains? The different domains were listed in the survey, and is a summary of all courses and topics that the 11 partners in the project intend to offer as open courses, in total 29 domains. The survey was accompanied with a document describing each subject. In this way we wanted to get feedback on the relevance of the domains. The list can be grouped in six main fields:

Fundamentals:

- Basic electronics
- Introduction to nanoelectronics: science & technology basics
- Transportation in micro and nano systems
- Nanoelectronics quantum phenomena in nanoscale systems
- Functional nanostructure: synthesis, characterizations and device applications
- Nanoelectronics: Processes, Computation and Design
- Microelectronics technology
- Nanomaterials synthesis and characterization techniques
- Sensing at the nanoscale

Materials:

- Nano Electronic materials
- Nanoscience of materials/ properties of nanoelectronic materials
- Carbon nanotubes and applications
- Graphene nanoelectronics: from synthesis to device applications

Devices:

- Design of nanoscale MOS ICs
- Top-down ASIC design flow
- MEMS design
- Advanced nano-electronic devices: miniaturization of transistors and their performance
- Sensor interface
- CAD for Microsystems
- Nanoscale Elements for Electronics and Sensing: Design and Device Production

Advanced nanoelectronics:

- Nanoelectronics Systems: Future Nanoeletronic Devices and Manufacturing Processes
- BioMolecular NanoComputing
- Memristor-Based Neuromorphic Systems

Applications:

- Bioelectronics
- Nanoelectronics for ICT
- Nanotechnology for solar energy utilization
- Advanced optoelectronic instrumentation & materials

Nanoelectronics and Society

- Socio- ethical and environmental aspects of nanotechnology/nanoelectronics
- Nanoelectronics systems: present and future business and manufacturing systems

B. *Survey for Staff and Teachers*

The survey for staff and teachers was also targeting universities in the partner countries in China, India, Malaysia and Israel. First, the respondents were inquired about general information (kind of job, type of institution and educational level at the institution). Next, the respondent's use of OERs was examined:

- Within engineering/ technology, does your institution use OERs?
- In case of using OERs, how often do you use them?
- What advantages/disadvantages do you consider that the use of OERs in education have?

Lastly, a list of domains (similar as for the industry survey) was presented. The respondents were asked to identify the domains that his/ her institution and students would benefit from having access to via OERs.

C. *Survey for Students*

Students from the partner universities in Asia were invited to participate in a survey to get an understanding of their use of and preferences of open educational resources. The questions covered if OERs are currently being used in the student's study programme, whether they are using OERs from other institutions, how often are they using OERs, and if they want to be involved in OER activities in the near future.

III. Results and Discussion

A. *Survey for Industry*

In total, the survey for the industry got 115 respondents. 31 from China, 32 from India, 36 from Malaysia, 8 from Israel and 8 from other countries (European). Fig. 1 shows the distribution of responses between the countries and the business category of the participants. We aimed to target human resource officers, process and design engineers, project leaders and managers. Reaching the first category was unfortunately unsuccessful (only a few respondents) and as many as 42% ticked off the category "other position" leaving the uncertainty in what background the respondents have. The distribution of the respondent's company size is shown in Table I. From China there is a majority of large companies (more than 1000 employees). This corresponds well with the results in Fig. 1 showing most of the Chinese companies are doing manufacturing. On the other side, 79% of the companies from India and 59% from Malaysia have less than 200 employees.

The companies' average need for competences within specific domains on a long term (more than 3 years) point of view is shown in Fig 2. The graph gives a picture of both the expressed needs and the estimated number of employees needed. Notice that the numbers are absolute. Hence, for a large company with over 1000 employees it is far easier to employ 10 new persons, than it is for a small company with only a few employees. The two ways of mapping industry need is coherent and shows the same tendency. The majority of the domains or courses ends up somewhere in between a low need (1-2 employees) and average need (3-7 employees). *Basic electronics*, *Introduction to nanoelectronics science & technology basics* and *Microelectronics technology* gets highest

Table I. Distribution of company size in number of employees.

How many employees does your company have?					
Employees	**1-10**	**11-50**	**51-200**	**201-1000**	**1000+**
All respondents	8%	28%	21%	11%	32%
China	6%	10%	10%	0%	74%
India	9%	49%	21%	3%	18%
Malaysia	3%	19%	36%	25%	17%
Israel	13%	50%	0%	25%	12%
Other	25%	38%	12%	13%	12%

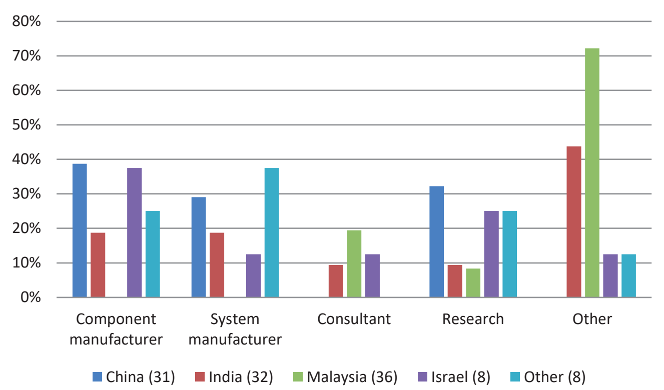

Fig. 1: The distribution of responses between the countries and the business category of the participants. The number in the bracket represent number of respondents.

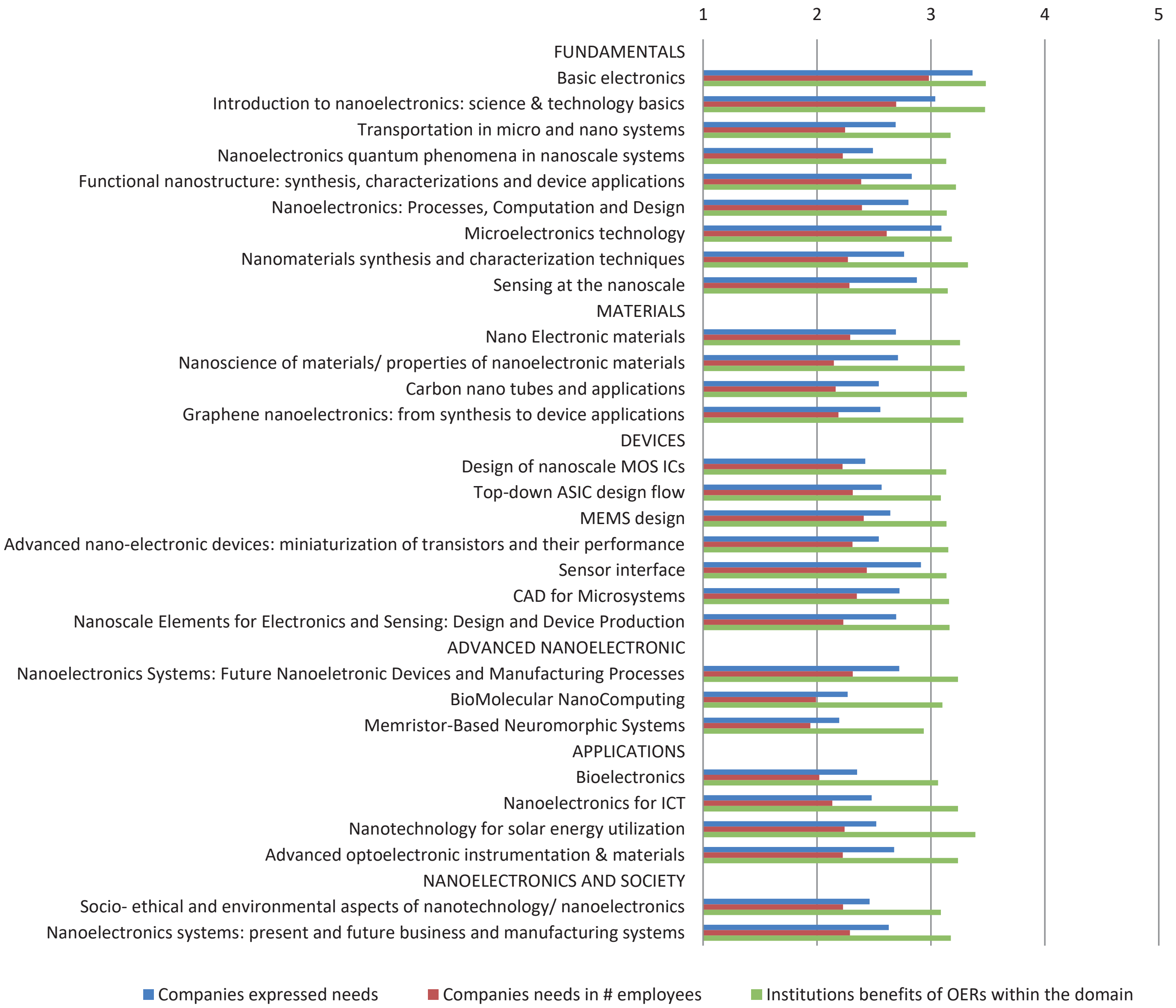

Fig. 2: The blue bars shows the companies expressed need for competence within the listed domains (1=no need, 2=low need, 3=average need, 4=high need, 5=mandatory). The red bars are the companies estimated need in number (#) of employees (1=0, 2=1-2, 3=3-7, 4=8-15, 5=15+) within the domains. The green bars shows how the teachers think their institution and students will benefit from having access to OERs within the listed domains (1=not at all, 2=low, 3=average, 4=high, 5=very high).

score and above the average need. These are all fundamental courses which should be relevant for all companies working within the field of micro- and nanotechnology. The courses with lowest score are Design of nanoscale MOS ICs, *Memristor-Based Neuromorphic System*, and *Bioelectronics*. These are more specialized courses and hence more relevant for niche companies. Even though this survey has its limitations, there is a tendency towards a mean interest for the multitude of subjects. If so, it can be difficult for one university to offer a multitude of specialized courses since the need for each of the specialized courses may be limited.

Looking closer on the feedback, Malaysian companies have in general lower needs, with a few exceptions, compared to the other countries. This may be explained by the fact that Malaysia is still at an incipient stage when it comes to micro- and nanotechnology innovation. Comparing the two large Asian countries, Chinese companies seem to have slightly higher need for competences than India. The exceptions are within bio- and solar energy related subjects in addition to subjects within nanoelectronics and society, where Indian companies scores somewhat higher. The difference may reflect that the respondents from the two countries covers different business areas and hence are not fully comparable.

B. *Survey for Staff and Teachers*

In the survey for staff and teachers, we got feedback from 90 persons, mainly university teachers. 74% of the respondents claims their university uses OERs within engineering and technology. Among the remaining, the main reason for not using OERs is actually that they are not familiar with these resources. Others see no benefit or they think it is too complex. In the case of how often OERs is being used, there is a spread. 14% uses it rarely, 35% uses it occasionally and 30% uses it frequently. The remaining 22% do not use OERs. Fig. 3 shows the feedback when asking what advantages they consider the use of OERs in education has. Between the different statements; *Cost efficiency*, *Reusability*, *Mobility of teachers/students* and *Connectivity of teachers/students*, there is an even distribution. *Flexibility and adaptability* is what most thinks is advantageous.

The respondents reflecting on the disadvantages of using OERs in education have different views. Some think that no face-to-face interaction is a drawback. The teaching becomes less interactive and there is a risk of low engagement for the students. Student's possibility to ask questions in the class, initiating discussions among the students and between teacher and students will not be the same. For some, the low or unstable access to internet is a hinder. Another argument against, is that the quality and reliability of the current available OERs is a challenge. There are many options and it takes time to distinguish between what is good and not so good. In addition, it can be difficult to organize and integrate OERs efficiently into the teaching. In technical courses with laboratory sessions, some think OERs are not relevant.

The teachers were introduced to the list of different domains within micro- and nanotechnology and at the same time asked if their institution and students would benefit from having access to OERs within these domains. The feedback is shown in Fig. 2. All topics score average or higher except one course. This indicates that the universities have an interest and a desire in offering the students a more diversity of topics.

C. *Survey for Students*

The survey among students has 286 respondents, of which 52% study micro- and nanoelectronics, electronics or informatics/information technology. The remaining is a mix of computer science, biomedical engineering, material science and chemical engineering students. 56% of the students are currently on Bachelor level, 27% are on Master level and the remaining are PhD students and postdocs. The majority of the students (78%) are in a programme that uses e-learning materials or OERs while the rest (22%) is not and hence they are unfamiliar with these kind of resources. As many as 53% of the students are using e-learning materials or OERs from other institutions and the remaining is not. Again, a lack of knowledge with OERs from universities elsewhere is the main reason for not using it. For students familiar with OERs, the frequency of making use of these support tools varies. 32% of the students use it rarely, 47% occasionally and 21% use it frequently.

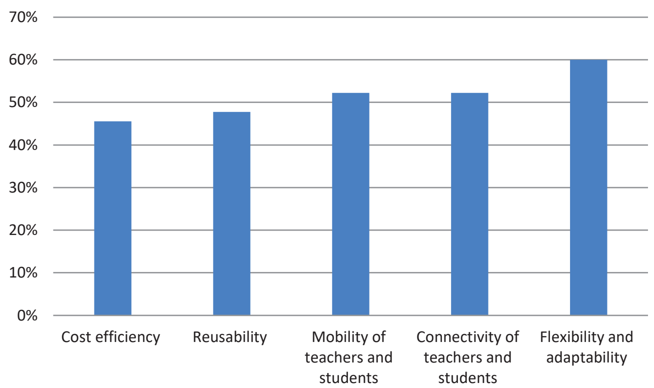

Fig. 3: Teachers feedback when asking what advantages they consider the use of OERs in education has.

We asked the students how often they have been participating in different learning activities in the past. The learning activities covers:

- Studying additional e-learning materials given by the teacher
- Searching for educational materials on internet
- Following Open Courseware(s) provided by other universities
- Watching recorded lectures or presentations given by experts outside your institution
- Working virtually with students from other universities internationally
- Carrying out experiments within remote laboratories
- Designing electronic/integrated circuits through remote access to the workstations

Then, the students where asked if they want to be involved in these activities in the near future. The results are shown in Fig. 4 and reveals that the students are eager and wants to take advantage of OERs if they are given the opportunity.

When it comes to benefits in using OERs in education: The majority (73%) of the students thinks flexibility and adaptability is an advantage. A lot (60%) also believes cost and time efficiency is an advantage. Less than half (42%) thinks that virtual mobility of students is an advantage while the connectivity of teacher and students is regarded as an advantage by only 39% of the respondents.

The survey clearly shows that the students prefer to use a multitude of OERs in the form of electronic books, interactive courses, powerpoint presentations and video recorded lectures. 73% of the students agrees or strongly agrees to that the use of OERs lead to improvement in learning. Furthermore, 67% of the students thinks that use of OER makes the learning content more attractive.

D. *Lessons Learned from Constructing a Survey*

Making surveys with questions not to be misunderstood is always a challenge, so also in this case. In retrospect, we see that some of our questions were unclear and could have been formulated better. Some of the unsuccessful questions have therefore been omitted in this paper. Despite the shortcomings in the surveys, there are tendencies in the feedback that gives valuable input to further work and development of the open educational courses. The complete surveys including answers can be found on the NanoEl project web page [5].

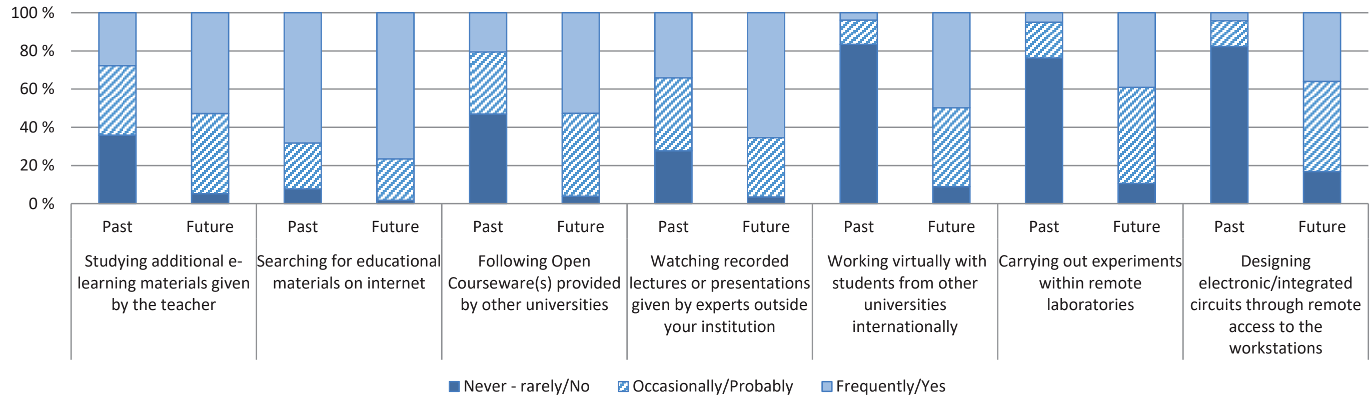

Fig. 4: Students feedback on how often they have been participating in different learning activities in the past and if they want to be involved in these activities in the near future.

IV. Conclusion

In this paper we have reported on results from three surveys targeting the industry needs for competence, the universities' need for and motivation to use open education resources and students' desires and interests in utilizing open education resources all within micro- and nanotechnology. The industry survey shows a mean interest in the multitude of subjects that the partner universities aims to offer as open educational resources. Among the universities participating in the survey, the majority is familiar with open education resources and appreciate the benefits of using them in the teaching. In addition, the survey indicates that the universities have an interest and a desire in offering the students a more diversity of topics within micro- and nanotechnology. The student survey shows that the majority of the students are in an educational programme that uses open education resources. The students prefer to use a multitude of open education resources, and agrees to that the use of such resources lead to improved learning and makes the learning content more attractive.

Even though the surveys have their limitations, the results provide valuable insights and input to the further development of the open educational courses in the NanoEl project.

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