Chapter 6
Online Nanoeducation Resources

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Abstract The internet has influenced all aspects of modern society, yet likely none more than education—opening new possibilities for how, where, and when we learn. Nanoscience and nanotechnology have developed over a similar time frame as the rapid growth of the internet and thus the use of the internet for nanoscience education serves as an interesting paradigm for internet-enabled education in general. In this chapter we give an overview of use of internet in nanoeducation, first in terms of available resources, then by describing the technological, philosophical, and pedagogical approaches. In order to illustrate the concepts, we describe as example a for-credit nanoscience curriculum which the authors developed recently as part of an international team.

6.1 Introduction and Background

The nature and emphasis of education in formal pedagogical frameworks as well as informal learning has been irreversibly impacted by the world-wide web and other rapidly changing technologies. Online resources have become a major source of information and knowledge, replacing texts and face-to-face (F2F) traditional courses. In the past decade, complete course materials have been made public, ranging from uploaded lecture notes to full video recorded class presentations. Various degrees of interactivity have been implemented in the different formats [1].

Whether it is medical assays, materials, or devices, nanotechnology has firmly rooted itself in our modern lives. In order to meet the growing need for scientists, engineers, and technicians to service and further develop this trend, the educational system must provide suitable training [2]. Nanoscience and nanotechnology, due to

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K. Winkelmann, B. Bhushan (eds.), *Global Perspectives of Nanoscience and Engineering Education*, Science Policy Reports,
DOI 10.1007/978-3-319-31833-2_6

their position at the cutting edge of new developments [3], characterized by rapid introduction of new material and high level of interest are particularly influenced by this transition in the learning environment. Thus, a myriad of online learning tools exist for nanoeducation. Nanoscience and technology has blossomed over the past 3 decades from a novelty to a mature science.

It is thus natural that these two trends—which have emerged and matured over approximately the same time frame—can serve each other. This situation has provided a fertile ground for extensive and creative use of the internet for instruction and learning in the nanosciences. This symbiosis takes on several forms:

1. Use of the internet for fact-finding. Using various search engines, or Wikipedia, students have come to rely upon the internet as the first-line source of information for short answers such as locating specific data or definitions, as well as literature searches for topics of interest.
2. Use of the internet as a tool. Researchers and students can access sites that allow them to perform problem solving whereby they can plug in parameters relevant to their experiment and the solution they desire is calculated for them. This can range from simple analytical solutions to a defined problem such as determining the spring constant of an AFM cantilever from easily measured observables to complex and comprehensive problem-solving such as running sophisticated simulations of a dynamic process.
3. Use of the internet for teaching. Lecturers in almost every institution of higher learning as standard practice upload their lecture presentations to a server that the students have access to before the lecture. This is the minimal usage. However, it is now possible to find for free, to purchase, or to subscribe in some fashion to full courses using different formats available today. This type of learning is available over the entire spectrum of higher education from undergraduate schools and through continuing education. For instance, many commercial companies now deliver and usually archive scientific webinars where the technology surrounding their product is taught. Participants are required to register for such webinars, and are subsequently able to ask questions which are answered in real-time by the lecturer.

The advantage of all of these avenues is that they allow sharing of resources within an institution, within a wider group, or even globally. This could be something as simple as a reference book with data on physical properties of nanoparticles, computing resources, or in the case of teaching, human resources.

Transition to online education requires a paradigm change in the way materials are taught, absorbed, and prepared, as well as changes in evaluation and credits [4]. Thus, even though F2F learning will not disappear quickly from the pedagogical environment, it will soon cease to be the main teaching methodology due intense demand for education. For instance, the student has become a much more central actor in the learning process and uses self-regulated learning skills which lead to two-way rather than one-way learning [5]. Furthermore, the different learning components (e.g., audio, video, slide presentations) can be utilized in a myriad of combinations and modes. These changes are taking place within the backdrop of increasing reliance on the internet as a formal and informal information source [6]. Despite this hype and obvious interest, the complexity of providing full and coherent courses which also grant credits toward a degree is a delicate and complex undertaking. From the basics of standardized and common credit units to coordinating the different courses which make up the curriculum with the available knowledge base of lecturers, to devising proper protocol of student evaluation, such an effort is clearly treading new ground. This chapter will survey and categorize the various resources available today in the field of nanotechnology education, and the nuances of their implementation, as well as provide an in-depth overview of a comprehensive program currently being developed by the authors and their partners—Education in Nanotechnologies, "E" under the auspices of the EU program TEMPUS (subsequently replaced by Erasmus+) [7]. This program aims to provide a broad offering of courses in nanotechnology for students, ranging from teachers interacting with middle and secondary schools, to undergraduates at both trade schools and universities, and on through graduate level university education and continuing education of professionals in the field. The topics covered include nanoelectronics, nano-medicine, nano-photonics, scanning probe microscopy, biosensing, atomistic simulation, and others. The courses are given by nanotechnology university researchers from an international team centered in Israel but including institutions from several European countries. This program provides the opportunity for students to expand their knowledge beyond the available courses in their own university.

The presentation of this project will provide a paradigm for study into the advantages and challenges associated with proper online learning such as technical means available for recording and disseminating the information, evaluation methodology, granting of credit, and logistics of collaboration between the teachers and teaching facilities which are geographically dispersed. From the basics of standardized and common credit units to coordinating the different courses which make up the curriculum with the available knowledge base of lecturers, to devising proper protocol of student evaluation, such an effort is clearly treading new grounds. The concept capitalizes on the ability to "bring" students from the different locations to an expert-level course provided at another institution. Thus, maximum utilization of human resources is achieved in a uniform, degree granting program.

6.2 Overview of Online Resources

According to the Foresight Institution, the first time the word nanotechnology was used, was by Taniguchi in 1974 [8]. Nonetheless, many credit the first proposal to Physicist Richard Feynman in a talk in 1959, "there's plenty of room at the bottom" [9]. It took over one decade for the first nanotechnology course to be offered (Stanford, 1987), and the first textbook came in 1992 [10]. The first company dedicated to nanotechnology, Zyvex, was founded in 1997. Today, a

Table 6.1 Some of the main U.S.-based online nanoeducation resource sites

Name [url]	Description	In this book
National Nano-technology Infrastructure Network [11]	Network of centers providing facilities for doing nanoscience	Chapter 4—History and accomplishments of the NNIN program by Nancy Healy
AtomicForceMicro [12]	AFM education	Chapter 10—Perspectives on AFM Education by V.A. Moore, A.C. Pic, N.A. Burnham
Mooc List [13]	By searching from this page with keyword nanotechnology, a list of online MOOCs in Nanotech-nology are displayed	No
Nanotechnology Center for Learning and Teaching [14]	Facilitates communication and dissemination of STEM	No
Nano-technology Knowl-edge Infrastructure [15]	Sharing nanoresources from variety of institutions	No
nanoHub [16]	Multi-faceted including data-bases, online simulations, pre-sentations, short courses, and more	No
Nano-technology and Applications Career Knowledge Network (NACK) [17]	Free resources for nanoeducation development	No
TryNano.org [18]	An open resource for anyone interested in learning about nanoscience and nanotechnology	No
Nanoscale Informal Sci-ence Education (NISE net-work) [19]	Bringing nano to the public	Chapters 1 and 15

Google search with the word "Nanotechnology" will yield over 23 million hits, whereas "Nanotechnology courses" retrieve nearly 1.2 million hits.

In this section, we will give an overview of a sampling of some of the online nanoeducation sites. Due to the sheer volume of these resources, and considering the nature of this chapter, we will limit these to sites focusing on higher education, and those in the English language. Even within these restrictions, we will only be able to cover a fraction of the many resources, however these are chosen to represent the types of nanoeducation resources now available on the web. A few of the important resources can be found in other chapters in this book. These sites are summarized in Table 6.1.

Many of the sites listed are umbrella sites that bring together a number of resources of value to the nanoeducator/student/researcher. For instance, the NNIN site is supported by 14 different National Science Foundation-supported nanocenters. In principle, this network is set up to facilitate research in the nanosciences by providing facilities that can allow researchers to visit and perform analyses, prepare samples, etc. while taking advantage of the local infrastructure and expertise. Some activities can also be performed distantly. The site also has an extensive portion dedicated to nanoeducation. In their words, they "take advantage of the size and breadth of the network to make a national impact." Although many of these programs are dedicated to the K-12 level, they also facilitate undergraduate students, as well as teachers and researchers and even the general public. A number of videos/webinars are provided including simulation techniques, equipment training, and relevant lab procedures.

NanoHub is a rich site which needs to be discussed in depth. This resource was created by the National Science Foundation-funded Network for Computational Nanotechnology, but it is now a global effort, active in over 170 countries. Indeed, there are a number of resources which focus on computational simulations for the nanosciences, the educational aspects of which will be discussed below. This site boasts over 300,000 users per year, split relatively evenly into US, Asia, and Europe—these three accounting for 90 % of the total usage. However, the geographic breakdown for specific tools is more disparate—for instance, nearly 50 % of the simulation users are from the US.

The NanoHub site includes extensive nanoeducational material, which is designed to be easy to use and intuitive. The educational page includes introductory videos on nano by several leading scientists, as well as more in-depth lecture material sometimes representing an entire course. One of these groups is NanoHub-U, a set of free, self-paced courses on nanotechnology. These courses include quizzes and provide a certificate of completion. There are both full-semester courses and shorter units. Topics range over the gamut of nano areas: nanobio, nanoelectrical, NEMS, as well as general topics such as physics, chemistry, and materials science. These latter recognize that nanosciences have developed from the traditional sciences which are a necessary pre-requisite to the more advanced concepts of nano. In addition to the formal course format, there is an extensive selection of shorter lecture series or presentations termed "popular topics" covering subjects such as AFM, Bio-NEMS, and thin film solar cells.

As mentioned above, NanoHub was born from the discipline of simulations. The site contains over 350 simulation tools. These tools are continually being developed and augmented as members place their own simulations on the site. A new simulation tool must meet a few basic criteria: it must address a specific problem faced in the nanosciences, must contain at least one complex (i.e., not a simple linear equation) mathematical model which is made into a simulation, and should be intuitive and interactive. These simulations can be used in a variety of ways—after teaching about a particular phenomenon, the instructor could ask students to run simulations on different scenarios to see how input parameters effect the results—for instance, influence on the optical spectra of nanoparticles on their size and material dielectric constant can be investigated, or current-voltage characteristics for Field Effect Transistors (FETs) displayed for different device sizes, geometries, and doping profiles. Since these are sophisticated simulations, advanced students could even use them to compare experimental results with theory, or to select parameters for a real experiment in the laboratory.

One interesting use of simulations is found on the page “Nano Education Research” [20] which includes a number of projects/simulations for building courses. In one of these projects the concept *Model Eliciting Activities* (MEAs) is introduced, which encourages students to solve practical, complex problems by use of models [21]. This concept is then used to study roughness on the nanoscale from images formed by AFM. The range of complexity of the simulations is vast, and in fact preparing the simulations themselves is an educational activity since capabilities of upper-class undergraduate and graduate students enable them to take on such activities as a classroom or research project.

The National Applications and Career Knowledge (NACK) site was specifically set up using support from an NSF grant to foster a workforce that meets the needs of the nanotechnology sector through 2-year programs, teacher training, and various resources including even a job-search link. Through a network of partners spread across the US, and spanning 2-year and community colleges, universities, and NSF-Advanced Technological Education Centers, the program reaches out to students and educators across the country. Although the resources are said to be developed at Penn State, we can find on the site information and links to such partners not only throughout the US, but also around the world. Resources provided include remote instrumental access allowing internet-based, online control, course lectures in HTML, or video format, and webinars (providing a certificate of completion) on such topics as graphene and other 2D electronic materials, self-assembled monolayers, and others.

In a comprehensive effort to augment and improve the nanotechnology workforce, the site recently published a pamphlet “Handbook for Processes and Best Practices in Nanotechnology Workforce Development [22].” This pamphlet draws on the experience of nanotechnology educators from around the country and provides advice on subjects ranging from industry surveys to student recruiting, from publicity in local media to curriculum development, from internships to on-campus outreach. There are numerous real examples, and links to the programs and institutions doing these activities.

Visiting these sites one is immediately struck by the extent of free nanoeducational content available on the web. For instance, the MOOC (Massive Open Online Course) list of *Coursera* includes about a dozen courses, covering fields that such as graphene science, nanosensors, nanocomposites, as well as general courses in nanotechnology. Furthermore, several courses with the keyword of nanotechnology appear including quantum mechanics, chemistry, and even innovation. Most of the sites listed in Table 6.1 are resource sites which contain many different types and levels of learning activity, as well as links to other projects and programs.

6.3 Technological Aspects

The blossoming of online learning and widely emerging online course repositories as described earlier is mainly due to the development of computers with high computation power and the availability of fast internet connection everywhere encompassing laptops, tablets, and mobile hand held devices. The constantly growing need for learning and education in an environment which is becoming more and more technological is also one of the main reasons making online learning so popular and essential. Whereas most of the details of this section are general for online learning technology and not specific to nanoeducation, their inclusion here provides essential background information. Furthermore, we hope this information may serve to aid those wishing to embark on similar projects.

Recent developments in the field of computers, computer network infrastructure and digital media encoding algorithms has facilitated vastly improved technology for enhanced F2F and online learning environment. In the last decade or so, the internet connectivity available to domestic consumers in developed countries grew from the order of several kilobytes per second to megabytes. Commonly available desktop/laptop computers or even hand held devices such as smart phones or tablets have more computational power than what were considered to be high-end computers of 15–20 years ago. The very high encoding (compression) ratios which have become available recently enable large amounts of data to be transferred over the internet, while consuming only a relatively narrow bandwidth.

The technological developments mentioned above are affecting education in many aspects and bringing about new paradigms such as "putting the student in the center", "recognition vs accreditation", "hybrid learning" or "flipped classroom" [23]. The pedagogical approaches have become more diverse and dynamic in order to catch-up with rapidly emerging new technological tools. Many Learning Management Software (LMS) systems have been developed recently either commercially or by open source communities. The usage of this kind of software enables learning on large scales as in MOOC's.

One of the most recent paradigms/tools for enhanced learning is "adaptive learning". Adaptive learning makes use of an intelligent LMS which adapts and customizes the learning process to learner-specific abilities and skills. If, in the traditional F2F teaching/learning mode, each student needed to adapt himself to a single teaching style regardless of his own learning skills or profile (which have been proven to be very different in terms of speed, memory and thinking styles [24]) in an adaptive learning process, the software monitors the individual student's learning and adapts/adjusts the rate of learning and the difficulty level in a way that optimizes the whole process. Most probably, although the F2F traditional learning will remain as a part of the educational environment, it will cease to be the main teaching methodology in the near future due to an exponentially- growing demand for education which can be met only by using technology- enhanced teaching/learning processes.

There are different formats for online learning courses, encompassing a wide variety of resources. The course content is usually provided as video podcasts. Kay summarized four forms of video podcasts that have been used: (1) lecture-based (2) enhanced (3) supplementary and (4) worked examples [1]. Lecture-based video podcasts are recordings of full lectures that the lecturer gives frontally. Students can review the lectures after the F2F lesson or instead of them. An enhanced video podcast is a video of a slideshow presented with an audio explanation. Supplementary video podcasts augment the teaching and learning of a course and include administrative support, real-world demonstrations, summaries of class lessons or textbook chapters or additional material that may broaden or deepen student understanding. Finally, worked examples provide video explanations of specific problems that students may need to solve in a particular course, often used in the area of science or mathematics.

In addition to video podcasts, online courses include supplementary components that enhance learning. These include links to external online materials (e.g., simulations, animations) that can explain abstract concepts [25]. They can also provide an interactive platform for student-student interaction in a forum or a Social Network Site (SNS) (e.g., Facebook). Garrison et al [26] found that to build a fruitful online community of inquiry (namely a learning community) three dimensions should exist: cognitive presence, social presence, and teaching presence. The podcasts represent the cognitive presence, the forums or SNS provide the social presence and the teaching presence is provided by the learning management system of the online course [25].

One of the most complicated strategic decisions in choosing the right LMS, video recording format or video/audio equipment is related to the anticipated future developments in the field and how the chosen strategy would support a fruitful online learning experience. Several reasons stand behind this conundrum. Most of the time there is more than one technology which can meet each learning need. The rapid development and concomitant drop in prices has led to shifts in the technologies used, hence older ones cease being supported and become hard to maintain. As an illustrative example[1] we consider the video compression/streaming solutions, developed by a variety of independent companies or open source communities leading to serious compatibility problems amongst them. Until about 10 years ago, Microsoft video solution by Windows Media Encoding codec (the word "codec" is a combination of the words "coder" and "decoder") dominated the video recording and streaming field and was installed on most computers utilizing MS Internet Explorer. In the last decade most of the video usage shifted to Flash and recently to H264 codec. Such rapid changes in the technological environment force institutions

[1] Here, and elsewhere specific products are mentioned to illustrate a point. These are not intended to endorse or cast aspersions on any product. The reader should keep in mind that technologies change rapidly and up-to-date information should always be sought, for instance from institutional IT office.

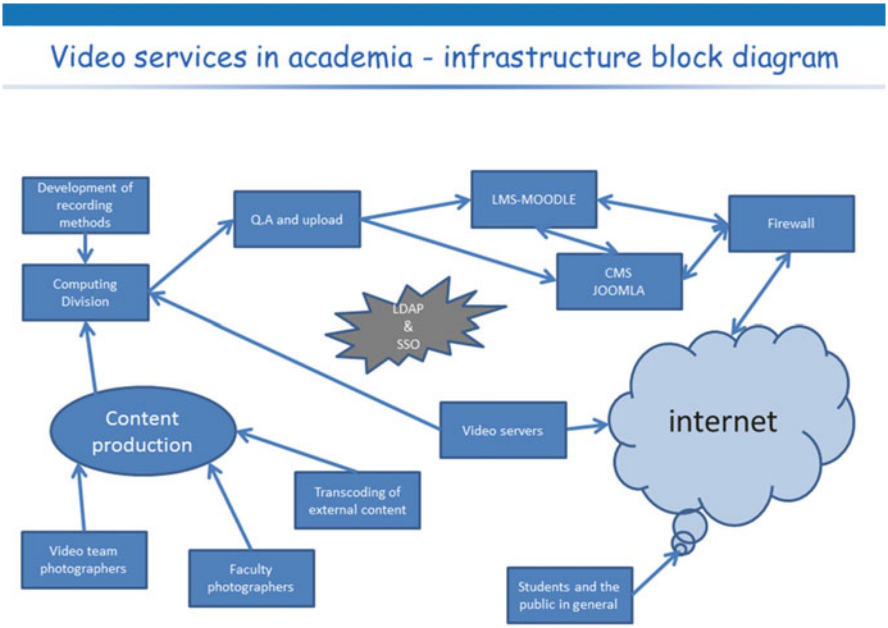

Fig. 6.1 Typical end-to-end workflow—from content production, to consumption by the students (here as used at Tel Aviv University). The lecture video recordings are done either by video recording teams in the classrooms (using mobile video recording gear) or by permanently situated cameras on location. At the post production state the recordings go through simple editing/ trimming and then a QA process just before uploading to video server and LMS. The uploaded content is available to the students by all end point devices like laptops, tablets or smartphones

of higher education to frequently change their video and learning management infrastructure at the expense of large resources in terms of funding and labor.

In Fig. 6.1 a schematic is presented for typical course video recording systems as adopted by some universities (in particular, the Tempus EduNano project to be discussed below).

A lecturer's video can be used either as live, synchronized "one to many" TV like broadcast, or video on demand asynchronous (VOD) so the learners can access them on their own time. In order to make high quality video available on the internet the video needs to be compressed with very sophisticated algorithms to reduce its original file size (uncompressed video can contain over 12G per hour of recording). The video compression is done by video codecs. Most of the codecs involve "lossy" compression, meaning that due to the compression they will lose a small fraction of the information in order to reduce the size of the compressed file significantly (typically from gigabytes to megabytes). When dealing with compression one needs to distinguish between "media packages" and "video codec". The former usually describes the content of the compressed file like in the "zip" files and the latter concerns the video compression and decompression algorithm. MPEG 4 and Flash are examples of Media packages, vp8 and H264 are examples of video codecs.

In addition to choosing the right video encoding format, it is important to have the proper recording equipment in order to perform high quality recordings optimized to web utilization. For locating and purchasing such equipment, there is a need to monitor the rapidly changing market, which continually offers better quality equipment for less money.

Currently, most of the Full HD low end video cameras provide a proper solution for standard size class room lecture video recordings. For a standard classroom in which the lecturer doesn't use a projector, other than the video camera, a tripod and wireless neck microphone will be sufficient as basic recording gear. When the recordings go to mass production it would be advisable to connect the camera to a computer so that the recorded file will be created in real time on the recording computer and can be uploaded to the web in a short time without the need to download it from the camera and transcode to a format suitable for streaming. For more complicated classroom recording scenarios such as lectures making use of slideshow presentations, or rich media presentations, there is a need for additional hardware equipment or software to record the lecturer's desktop activity. The situation becomes even more complex when the class takes place in large auditoriums with sophisticated audio/visual equipment. Connecting the recording gear to new digital era modern lecture hall audio visual equipment often requires highly professional technical staff.

Producing the video recordings in specially equipped rooms such as video recording studios can be a good option, as an alternative to recording in regular classrooms. Such recordings have of course pros and cons: very high operational and maintenance cost. Most of the lecturers do not feel in their native environment when they give their lectures in a recording studio where usually there is no room for the audience. When high quality video recordings are required, despite these disadvantages, recording in a studio is the preferable option.

The digital video compression algorithms mostly detect the changes between successive frames and process only the changes from the current frame to the previous one. This is the reason why the amount of the information required for the recording/streaming is directly correlated to the amount of motion captured by the camera (see Fig. 6.2).

In order to get the optimum video quality in a given bandwidth we need to try to reduce the amount of the motion captured in the video frame while filming. Using a tripod is extremely important in order to stabilize the camera and limit the amount of unnecessary vibrations which increases the amount of motion in the frame. When recording lectures in which we have talking heads (as in most webcasts) having a

Fig. 6.2 Difference coding only codes the first image, shown here on the *right*. Subsequent images reference the first picture for the static elements, i.e. the house and tree. This static *grey* background is not transmitted. Thus, it is only necessary to code moving parts—the car—which vastly reduces the data that must be processed

static unchanging background can improve the video quality. Good lighting conditions that eliminate noisy background also enhance the video quality.

Before the recordings, it is very important to brief the lecturer on some basic rules regarding how to perform in front of the camera during the recordings. It is recommended to wear clothes with colors in contrast with the background such as wearing a dark jacket while the background is white or very bright, not using cloths with vertical or horizontal lines and trying to limit lecturer movement as much as possible (such as not running rapidly from one end of the board to the other). In case of large boards a good practice is to divide it to two or three segments which fit the camera frame and ask the lecturer to move from one sector to the next only when writing space in the current segment is filled.

Having good audio quality is even trickier than fine tuning the video during the recordings. Using the internal microphone of the camera is not a good option since the camera is usually situated at the back end of the classroom just in front of the lecturer and every whisper of the students sitting nearby will be recorded louder than the lecturer's audio. A wireless neck mic attached to the lecturer can solve the problem providing good audio recording quality.

Whenever the lecturer makes use of a projector to project slides it is advised to capture the lecturer desktop digitally and not to film it from the screen, since it would be too bright in contrast to the lecturer image and it would be almost impossible to combine in one frame the lecturer image and the slides.

There are various frame grabbers which can split the VGA/DVI signal from the output of the lecturer's computer and send it to the recording computer in order to embed the slides digitally in the video frame. An example showing a screenshot of embedded lecturer desktop presentation with simultaneously recorded video is shown further below, in Fig. 6.3.

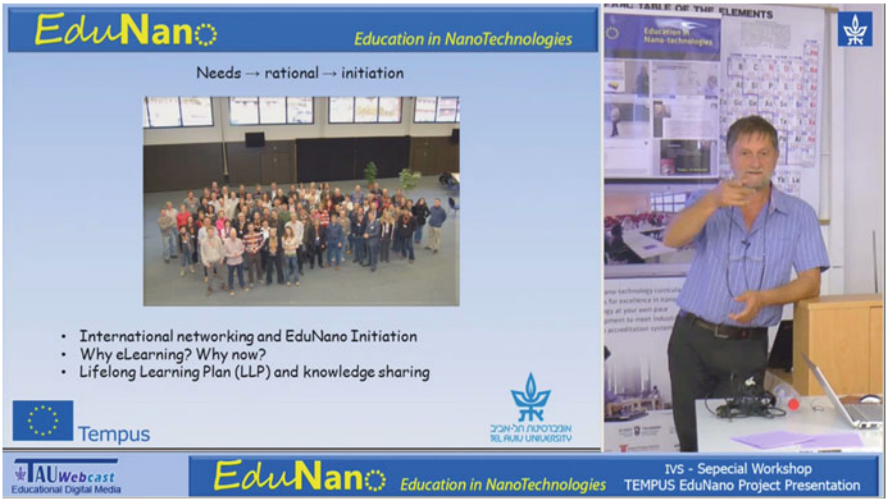

Fig. 6.3 Screen-shot from video from Tel-Aviv University recorded in real-time in front of a classroom using specialized software

6.4 EduNano Project

6.4.1 History and Background of the EduNano Project

To illustrate the concepts presented in the first part of this chapter, we devote the rest of this chapter to a detailed description of the EduNano project, an EU-funded e-learning project coordinated between ten different institutions in four different countries. This program addresses educational needs from K-12 teachers and on through undergraduate and graduate students, as well as continuing education. In order to accommodate the latter, the consortium includes an industrial partner. The program grants EU-approved university credits, and provides a wide spectrum of courses in the nanosciences.

The center-of-gravity for the program is in Israel, as the idea germinated from a formal initiative termed the Israel National Nanotechnology Initiative (INNI). This initiative strove to lead and guide collective efforts and promote research and development in the nanotechnologies while emphasizing strong collaborations between academia and industry. In 2007, the Israeli government, jointly with the Israeli National Academy of Sciences, set national goals for advancing nanotechnology in Israel to achieve critical mass and world-class infrastructure within a 5-year program. As a result, significant government and university matching funds were allocated for the first 5 years of the program. The outcome of the program after these first 5 years was impressive: six world class nanocenters were established which include 325 senior faculty and about 1100 researchers, 85 companies were formed, and 185 patents granted (INNI). Following this, a second 5-year term was approved with emphasis on education, under the realization that this program could only be sustained over the long-term if young researchers, engineers, and technicians continue to be trained in the relevant fields.

The recognition of the need to develop educational resources in order to support the development of nanotechnology is quite general. Roco emphasized the importance of education for the future development of nanotechnology: "One of the 'grand challenges' for nanotechnology is education, which is looming as a bottleneck for the development of the field" [3]. The same notion is reflected in official EU reports: "In knowledge-intensive and growing sectors such as nanotechnology, there will be even greater demand for scientists skilled in more than just one area of research [27] and in the global scientific community" the studies in this area (nanoelectronics) point to the urgent need to further develop scientific education and training with a particular stress on interdisciplinarity [28].

However, there are very few individual research teams, laboratories, companies, or even universities that can reasonably claim to be capable of responding to the technological challenges. Even big companies in the sector work with common R&D resources (such as Motorola and ST Microelectronics). To host all necessary infrastructure, including clean rooms, fabrication and analytical equipment, supporting technology and experts in all the multidisciplinary fields of nanotechnology in one location, is an enormous challenge.

6.4.2 Concept of the EduNano Project

EduNano strives to meet these challenges of future nanotechnology educational needs to provide high-quality online educational material which tracks key scientific developments. EduNano harnesses the power of distance learning to globalize the nanotechnology knowledge base, and to provide a variety of learning opportunities for different target audiences.

The goal of EduNano is to promote nanotechnology excellence, via distance-learning opportunities that will benefit everyone from high school students and their teachers, to university and graduate students, academic researchers, technicians, and industry professionals. Conceived as a framework for inter-university cooperation, the EduNano consortium includes six Israeli Universities and research institutions—Bar-Ilan University (BIU), Ben Gurion University of the Negev (BGU), the Hebrew University of Jerusalem (HUJI), Tel Aviv University (TAU), the Technion (IIT), and the Weizmann Institute of Science (WIS)—as well as Italy's Politecnico di Torino (Polito), the Grenoble Institute of Technology in France (CIME), and Bulgaria's University of Sofia (TUS), the latter serving as the program's overall coordinator. The project also includes the company Elbit Systems—an Israeli electronics firm, allowing a direct connection between industry and academia in the nanosciences and technologies.

This project focus is on common course development for the new skills needed for new jobs in the multidisciplinary nanotechnologies. The EduNano project aims at modernization of curricula and lifelong learning through shared facilities and expertise in nanotechnology. The project capitalizes on the strengths of each member to provide a wide range of learning possibilities which are unattainable at a single university. The internet courses developed within the project provide new opportunities for co-operation between universities, high schools, research institutions and enterprises in sharing of knowledge and educational resources. The shared resources are to be used in the partners' M.Sc. and Ph.D. degree programs and in teacher training. The project focuses on close cooperation between the universities, requiring mobility and transparency of qualifications and recognition methods.

A central characteristic of the project is the extensive interaction amongst the lecturers. This has arisen naturally as the project guidelines require semiannual meetings, and frequent (often weekly) communications amongst the participants. Such meetings encourage collaboration, and foster sharing of experiences, good and bad, of the different approaches adapted by the member teams. When such encounters result in a lecturer deciding to try a new approach, they can naturally turn to the person that introduced it to them for assistance as necessary. This aspect of the course preparation is very different from what we have experienced for a frontal-teaching course, where we typically prepare our lectures alone in our office, and carry them directly to the classroom. This additional level of interaction provides a degree of peer critique, and furthermore provides an open forum for course improvement.

In this sense, the instructors can benefit from interactions with their peers in much the same way that interactions between scientific researchers lead to more collaborative work and better science. In much the same way that scientists attend conferences as much to get an overview of new developments in the field as to seek out their peers, make new acquaintances, and engage in conversations which often lead to fruitful new ideas and collaborations, a close interaction amongst instructors is essential in pushing forward the teaching methods and approaches developed or used by each. All of this can be achieved without even reviewing the lecture content from other courses. But when content is also shared (for instance by hyperlink from one lecturer's presentation to another course that expands on a specific topic) the full power of the strong collaboration can be exploited.

6.4.3 Course Development Within the Universities

In order to achieve the goal of shared resources, the courses have been carefully designed to comprise certified modules, based on ECTS (the European accreditation method). The ECTS credit points can then be formally applied toward degree work in the corresponding partners' courses. Each course is designed by that laboratory/department in the field which has the necessary infrastructure, facilities, and teaching capabilities. They develop e-learning courses, record lectures and offer the possibility for practical work in clean rooms in nanotechnologies. Despite the shared resources, each university keeps its autonomy regarding granting degrees and diplomas. The implementation of the joint courses will start during the year 2016 as a part of the regular educational practices at each partner university.

The following is a list of the courses given by the different partners of the EduNano project:

- Advance Topics in Nano-Photonics and Quantum Structures (BGU)
- Advanced Materials and Nanotechnologies for Electrochemical Energy Storage (Elbit Systems)
- Atomistic Simulation of Materials (TAU)
- Biochips and Nanostructures Analysis (CIME)
- Bio-Nanoelectronic Devices for BioSensing (Polito)
- CAD for Nanoscale Transistors (TUS)
- Design of Nanoscale ICs (TUS)
- Fundamentals of Nano-Biotechnology: Where Nanotechnology, Biology and Medicine Interface (Technion)
- Introduction to Materials and Nanotechnology for High School Teachers (Weizmann)
- Introduction to Surface Science (TAU)
- Kinetics of Materials (BIU)
- Macroscopic Quantum Coherence in Engineered Nano-Systems (HUJI)
- Molecular Electronics for the Realization of Novel Nanoelectronic Devices (Polito)
- Nanomaterials for Electronics (TUS)
- Nanomaterials from Nanoskills (TUS)
- Nano-Science and Nano-Technology. Why is "Nano" Different and How is it Useful? (BIU)
- Nanostructures Analysis (CIME)
- Nanotechnology—Journey Through Time and Space Towards Future Drugs (BGU)
- Nanotechnology in the Service of Humanity (HUJI)
- Quantum Mechanics for the Nano Program (Technion)
- Scanning Probe Microscopy and its Applications in Research and in the Nanotechnology Industry (Weizmann)
- Simulation of Microelectromechanical System -MEMS—Devices (TAU)

All the courses are available online in the project's Moodle (a website based on open source learning management software containing all the videos, activities and resources related to the educational program. For more information (see Refs. [29, 30]).

In order to meet the needs of academia and industry, two steps were made to support the final structure of the courses provided by the project. In the first step, each of the universities participating in the project suggested two or three courses in the field of nanoscale science and technology that are already successfully taught in the university. The course syllabi were examined by the partners and overlapping courses were removed while new courses were suggested to provide an interested and varied interdisciplinary offering. In the second step a need analysis survey was developed by the Shmuel-Neeman Institute (affiliated with project partner IIT). The survey included a description of the proposed courses which was distributed to and filled by 60 nanotechnologists in industry and academia in Israel. They were asked to rank the importance of each course for future workers (in industry) and future researchers (in academia). As a result of the survey, additional modification of the course list was conducted until we reached the final course list presented above.

Upon agreement of the course list, the partners participated in a workshop of writing and using learning outcomes. As stated in the Bologna Agreement [31], a key change required in formal education is the need to improve the traditional ways of describing qualifications and qualification structures: Each course should have clearly stated goals and competencies expected to be obtained through the coursework. As a step towards this goal, care was taken to define and provide learning outcomes. Learning outcomes describe evidence of learning in areas like knowledge, comprehension, application, analysis, synthesis and evaluation. Using learning outcomes for a course instead of the course syllabus shifts from the traditional teacher-centered approach to a student-centered approach, i.e. the focus is not only on teaching but also on what the students are expected to be able to do at the end of the course.

In general, when writing learning outcomes one begins with an action verb followed by the object of that verb. As a demonstration, the learning outcomes for the course "Scanning Probe Microscopy and its Applications in Research and in the Nanotechnology Industry are presented here:

Upon successful completion of this course students should be able to:

- Describe the fundamental components of any scanning probe microscope—*detection* of physical quantity measured; meaning of *setpoint*; *operation of control system* acting to reduce error signal by feedback; *transducing* voltage signal to motion.
- Predict the effect of various scanning parameters—feedback gain, scan speed, setpoint, on the image obtained.
- Know how to choose an appropriate probe for a specific sample and scientific problem.
- Decide which of the various modalities of scanning probe microscopy are appropriate for a specific sample/scientific question.
- Know the advantages and disadvantages of the technique relative to other microscopies.
- Critically read and review current literature which is based on scanning probe microscopy
- Identify artifacts in their work and that of others.
- Be familiar with realized and potential applications of SPM in practical and industrial environments.
- Propose standard SPM experiments for solving a specific scientific problem.
- Perform basic image manipulation and analysis procedures (levelling, filtering, histogram adjustment, statistical and grain analysis).

The proposed learning outcomes for the courses were reviewed by experts from the Hebrew University in Jerusalem and following the feedback received, the partners started to build and record the course lectures. In the next stage each institution chose a preferred mode of presentation, although in some cases, different lecturers within an institution used different approaches. Different considerations influenced this selection. The courses had to be full online courses and therefore three main options were feasible (1) lecture-based (i.e., no or minimal use of slideshows, for instance a film of a F2F lecture typically with use of whiteboard/chalkboard) (2) enhanced (combination lecture and slideshow) (3) HTML lessons (the course material is presented as text pages) [1]. In Tel-Aviv University full lectures were recorded in real-time in front of a student audience and were combined with the slides of the lecturer using software developed by Tel Aviv University. This approach was adapted by several other partners. Figure 6.3 presents a snapshot taken from a presentation using this approach.

There are several advantages in using this approach to produce video lectures: The video is recorded during a course that is given anyway in the university and the lecturer does not have to invest additional efforts. The software that connects the video of the lecturer and the slideshow presentation works in real-time and therefore the video is available immediately when the lesson is completed. However, there are some limitations as well. The resulting video length is about 45 min, which is considered to be too long for an online lecture. These can easily be edited to shorter segments in post-production although the break-points may not be as natural as in a preplanned shorter videoe4 clip. In addition, the interactions between the lecturer and the students in the class during the lectures that includes questions, clarifications and organizational issues are also recorded and makes parts of the video irrelevant for external students who take the course. Such segments can also be excluded by editing but in this case the format will lose the main advantage of short production time.

The second approach that was used in the project was to produce the lectures in a studio. The lecturer gave the lectures in front of a small number of students in a studio equipped with video-audio recording system. The quality of the sound and video in this approach is excellent and the lessons lack the distractions of a large student audience. However, this approach is more expensive (hiring the recording studio) and can be used only in academic institutions that have access to a studio environment. Bar-Ilan University used this approach, as presented in Fig. 6.4. A professional video editor combined the video of the lessons with the slideshow presentations and the combined edited product was uploaded to the learning environment.

The Hebrew University of Jerusalem also decided to record full lectures for the online course. One of the courses at the Hebrew University of Jerusalem used recordings of full lectures whereby the lecturer used a chalkboard to develop the physical equations, as presented in Fig. 6.5.

The three approaches presented above all recorded full lessons and used them to prepare the complete video lesson. An alternative option used was enhanced videos.

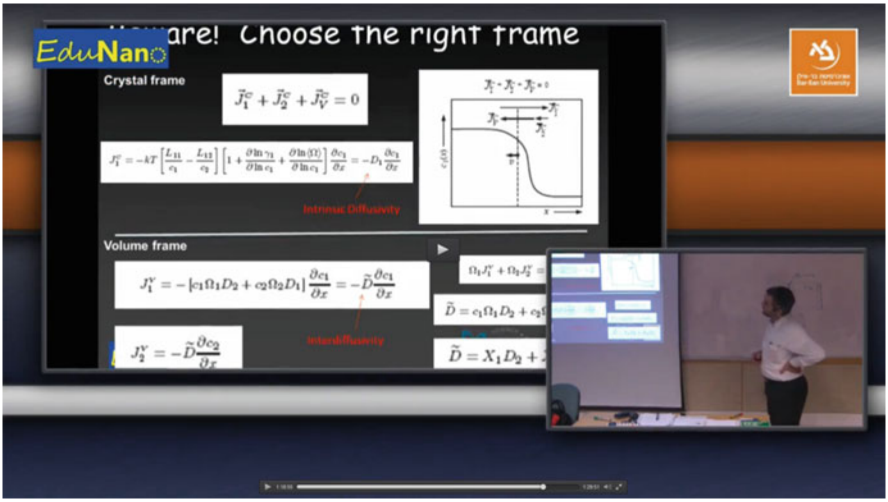

Fig. 6.4 Screen-shot from video of Bar-Ilan University recorded in a studio

Fig. 6.5 Screen-shot of video from the Hebrew University of Jerusalem where the lecturer used chalk and board

The Weizmann Institute of Science decided to build their videos using a commercial software package for preparing online course lectures. These courses were designed as short slideshow presentations that were accompanied by recorded explanations of the lecturers, as presented in Fig. 6.6.

The enhanced slideshow presentations are recorded directly into the instructor's computer without an audience. The advantages of this approach include the possibility to control the length of the videos and thus to split a typical lecture given in the university environment to several shorter clips. Each topic can be divided into short videos geared to keep the attention of the students who will watch them

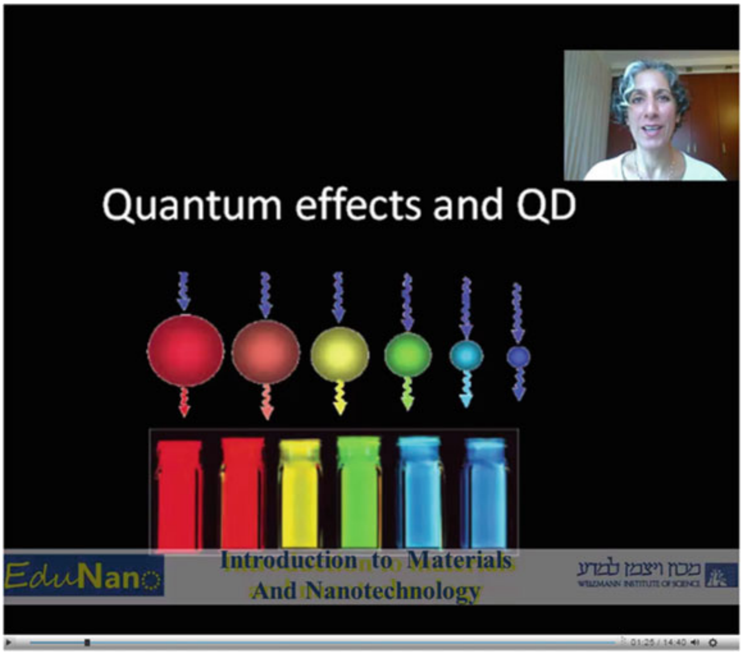

Fig. 6.6 Screen-shot from a video from the Weizmann Institute of Science using the approach of enhanced slideshow presentations

online. Recording the videos without students avoids the distraction of questions and comments from the audience during the lecture.

The software used also provides additional options such as integrating quizzes in the lectures, using zoom-in options and editing the video for creating a better product. Here also, there was a downside: in our experience, lecturers found it difficult to give an appealing talk in directly to a computer without receiving any feedback from students who watch the talk. The main disadvantage of this approach is that it is very time-consuming. The slideshow presentations had to first be modified to accommodate the screen setting of the final clip (video box at top, watermark at bottom (see Fig. 6.6). Here, as with a studio lecture, recording has to be done in addition to the regular teaching tasks, and the editing process could be very lengthy to get to a good final product.

TUS used HTML format. This format presents slides which students can click through at their own pace. Such slides are by nature, much more complex than a single slide in a frontal lecture and each one could contain several equations and much text. The pages also contain exercises which the students can work through as they learn the concepts. An example of a relatively simple HTML page is shown in Fig. 6.7. A major advantage of the HTML format is the ease with which it can be edited to add new or delete old material. The downside is that this kind of

Fig. 6.7 Example of a relatively simple page from HTML-based course *Design of Nanoscale MOS ICs* from the Technical University of Sofia

presentation is "dry" in that it cannot impart the excitement that a dynamic lecturer provides, nor the depth of explanation included in the audio track.

6.4.4 Challenges in Evaluating Online Academic Courses

This TEMPUS project is finishing its pilot run as this chapter is finalized. One of the major issues for a credit-granting program is evaluation and credit assignment. Different approaches will be used for course evaluation. The first approach is the traditional approach of examination. In this approach all students who take the course (F2F and online) will physically come to the university providing the course to take a written exam. The evaluation solution is possible in a small country like Israel (the participating universities are all located well-within a 100 km radius from the country center). However, if we consider students from other countries this solution cannot be used. Other courses, (e.g., the Weizmann introductory course for high school teachers) will use a final assignment that will be peer-reviewed. The students in the course (high school teachers) prepare a slideshow presentation and record their lecture on different topics in nanoscience, all sharing the same format. The lecture begins with the historical development of the topic, subsequently proceeding with the technological goals of that topic. Most of the lecture is devoted to the scientific aspects of the topic and its technological applications. The summary includes relevant Israeli contributions to the specific subject, technological advances related to the topic, future expectations, and critique. This part of the final report is similar to the assignment that is given in the F2F course [32]. Each student has to watch three other presentations and provide feedback according a given rubric. In addition to the final assignment, part of the evaluation is based on the students' participation in the weekly forum in which the students will be asked to discuss possible connections of the nanotechnology concepts to the existing chemistry curricula in Israel. A different approach will be attempted in the course: Scanning probe microscopy and its applications in research and in the nanotechnology industry (Weizmann). In this course short quizzes, embedded in the presentations are given. These are automatically evaluated and passed to the course lecturer. The quizzes are given in addition to a final project at the end of the course. The course Surface Science at Tel Aviv University gives full homework assignments which must be submitted electronically. In addition, the students gave short presentations to the instructor over Skype with a shared screen. In all approaches, the amount of lecturer input in the evaluation will necessarily limit the size of the course.

6.5 Summary

In many ways, successful education of our workforce—both present and future—in the nanosciences is the key to our future. In this chapter, we have provided an overview of how this task is being accomplished using a wide spectrum of online resources. Rather than attempting a comprehensive survey of the many excellent existing resources, we have chosen a sampling which provides the possibilities and challenges of online education in the nanosciences. In particular, we have provided a synopsis of the TEMPUS EduNano project as a paradigm for the challenges in for-credit online nanoeducation.

For educators, we hope that this material will provide not only useful examples, and tips on how to exploit the available technologies, but also a broad perspective of the issues, challenges, and possibilities available. For students, we feel that an understanding of the philosophy and motivation behind online education development will help guide the learning process. For general readership, we hope that this material will prove insightful and useful.

As we have noted in the chapter, technological advances in the preparation and dissemination of online learning materials may be progressing as rapidly as developments in nanoscience and nanotechnology. Therefore, we expect that significant improvements may emerge in this area and look forward to experiencing and benefiting from those changes along with the rest of this dynamic community.

6.6 Future Policy and Recommendations

As noted at the outset, and embodied in the needs analysis survey of the EduNano project, the motivation driving high-quality education in the nanosciences is the necessity to train a skilled work-force at all levels, which will be expected to assume key roles in the evolving technologies. The highly interdisciplinary nature of the nanosciences places pressure on the educators to provide relevant instruction in widely-ranging fields. Suitable technical education requires a hands-on learning environment which entails well-equipped laboratories housing often expensive equipment. To achieve this, funding will need to be allocated for many programs similar to EduNano.

It is clear that if such high-level training is to be available at any other than the auspiciously well-endowed (both financially and pedagogically) institutions, then the means to share the resources need to be exploited. Online learning is slowly becoming an established mode that can meet such needs, but there is a long-way to go in providing appropriate hands-on opportunities, and the ability to capitalize on knowledge base and educational skills in local, regional, or even national consortiums.

Whereas remotely controlled tools have become more practical in recent years, in many cases actual travel to the site is still the only solution. The mechanism for such mobility must be encouraged.

Furthermore, standards for credit-granting need to be widely accepted as with the ECTS described above. Evidence of similar developments include standardization of practices. For example, an ASTM (American Society for Testing and Materials, the now international organization that engages in the development and publication of international standards for materials, products, systems and services) workforce committee E56 was formed in 2005 to provide standard guidelines for nanotechnology needs and workforce practices in nanotechnology. This committee initiated the work item wk46489—New Practice for Standard Practice for Workforce Education in Nanotechnology Characterization [33].

Above all, we feel that the internet has provided an excellent opportunity for us to learn from our colleagues and by opening up teaching resources, we are making it much easier for educators to be up to date on the most successful technologies. We can only hope that the result of these innovations will be better education, which is open to a wider and more diverse student population.

Acknowledgments This project has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein. We further acknowledge the support of the Helen and Martin Kimmel Center for Nanoscale Science at the Weizmann Institute of Science.

References

1. R.H. Kay, Comput. Hum. Behav. **28**, 820 (2012)
2. N. Healy, J. Nano Educ. **1**, 6 (2009)
3. M.C. Roco, Nat. Biotechnol. **21**, 1247 (2003)
4. D.J. Karber, High. Educ. Eur. **26**, 533 (2001)
5. B.J. Zimmerman, Educ. Psychol. **25**, 3 (1990)
6. N. Selwyn, *Education and Technology: Key Issues and Debates* (Continuum International Publishing Group, London, 2011)
7. Erasmus + EU programme for education, training, youth and sport, European Commission. http://ec.europa.eu/programmes/erasmus-plus/index_en.htm. Accessed 17 Jan 2016
8. N. Taniguchi, in *Proceedings of the International Conference on Production Engineering*, Tokyo, Part II (1974)
9. Short History of Nanotechnology, Foresight Institute. http://www.foresight.org/nano/history.html. Accessed 20 Jan 2016
10. K.E. Drexler, *Nanosystems Molecular Machinery, Manufacturing, and Computation*, 1st edn. (Wiley, New York, 1992)
11. National Nanotechnology Infrastructure Network, National Science Foundation. http://www.nnin.org. Accessed 17 Jan 2016
12. Tutorials on the use of the NaioAFM at WPI, YouTube, https://www.youtube.com/user/AtomicforceMicro. Accessed 17 Jan 2016
13. MOOC list, https://www.mooc-list.com/. Accessed 17 Jan 2016
14. Nanotechnology Center for Learning and Teaching, Materials World Modules, Northwestern University. http://community.nsee.us/. Accessed 17 Jan 2016
15. Nano-technology Knowledge Infrastructure, US National Nanotechnology Initiative. http://www.nano.gov/NKIPortal. Accessed 17 Jan 2016
16. NanoHub, Network for Computational Nanotechnology. https://nanohub.org/. Accessed 17 Jan 2016
17. Nanotechnology Applications and Career Knowledge Network, Penn State University Center for Nanotechnology Education and Utilization, http://www.nano4me.org/. Accessed 17 Jan 2016
18. TryNano, IEEE, IBM, New York Hall of Science. TryNano.org. Accessed 17 Jan 2016
19. Nanoscale Informal Science Education, National Science Foundation, www.nisenet.org. Accessed 17 Jan 2016
20. Nano education research, (within site of ref. 16), https://nanohub.org/groups/edresearch. Accessed 17 Jan 2016
21. H.A. Diefes-Dux, M.A. Hjalmarson, T.K. Miller, R. Lesh, Model-eliciting activities for engineering education, in *Models and Modeling in Engineering Education: Designing Experiences for all Students*, ed. by J.S. Zawojewski, H.A. Diefes-Dux, K.J. Bowman (Sense, Rotterdam, 2008), Chap. 2, p. 17
22. Handbook for Processes and Best Practices for Nanotechnology Workforce Development, NACK Network, Pennsylvania State College of Engineering, http://www.nano4me.org/handbook/NACK%20Handbook%20-%201st%20Edition%20.pdf. Accessed 20 Jan 2016
23. M. Rosenfeld, S. Rosenfeld, Educ. Psychol. **28**, 245 (2008)
24. M.R. Young, B.R. Klemz, J.W. Murphy, J. Market. Educ. **25**, 130 (2003)
25. R. Blonder, S. Rap, Educ. Inf. Technol. **1** (2015)
26. D.R. Garrison, T. Anderson, W. Archer, Internet High. Educ. **2**, 87 (1999)
27. Communication from the Commission to the European parliament. An Agenda for new skills and jobs: A European contribution towards full employment, Strasbourg, 23.11.2010, COM (2010), http://ec.europa.eu/social/BlobServlet?docId=6328&langId=en. Accessed 21 Jan 2016

28. Investing in the Future of Jobs and Skills. Scenarios, implications and options in anticipation of future skills and knowledge needs for the Computer, Electronic and Optical Products Sector. Policy Summary, DG EMPL report VC/2007/0866, Lot 7, 05.2009
29. About Moodle, Moodle, https://docs.moodle.org/30/en/About_Moodle. Accessed 16 Jan 2016
30. Education in Nanotechnologies Project, EduNano, http://edunano-lms.tau.ac.il/login/index.php. Accessed 16 Jan 2016
31. S. Adam, Report on United Kingdom Bologna Seminar, *Using Learning Outcomes: A consideration of the nature, role, application and implications for European education of employing learning outcomes at the local, national and international levels,* 2004, http://www.ehea.info/uploads/seminars/040620learning_outcomes-adams.pdf. Accessed 21 Jan 2016
32. R. Blonder, J. Chem. Educ. **88**, 49 (2011)
33. Committee E56 on Nanotechnology, ASTM International, http://www.astm.org/COMMITTEE/E56.htm. Accessed 17 Jan 2016