nanoHUB-U: A Science Gateway Ventures into Structured Online Education

Victoria A. Farnsworth, Mark S. Lundstrom, Supriyo Datta, Ron Reifenberger, Arvind Raman, Timothy Fisher, Alejandro Strachan, Michael McLennan, Swaroop Shivarajapura, Lynn K. Zentner, Krishna Madhavan, Gerhard Klimeck

Network for Computational Nanotechnology, Purdue University, West Lafayette, IN 47906

***Abstract*— nanoHUB.org is arguably the largest online nanotechnology user facility in the world. From an initial user base of about 1,000 users, nanoHUB has grown to support over 250,000 users annually. nanoHUB supports users in 172 countries with materials for research and education, along with a wide variety of simulation tools covering many nano-related areas. Preliminary assessments of user behavior patterns have shown that nanoHUB's open access approach enables published resources to be integrated directly into classrooms. However, there is an increasing demand for pedagogically sound, workforce-ready, advanced courses that allow users to gain depth in topical areas related to nanotechnology. This paper explores an initial case study where an evolving cyber environment, based on the powerful HUBzero platform, begins to offer structured online courses to its massive audience through an experiment known as nanoHUB-U. This paper describes the impetus for this new offering and discusses how new and cutting-edge content formats are being combined with online simulations in significant ways. Further, it explores in-depth the outcomes related to one of the most popular courses offered to date.**

I. Introduction

The Network for Computational Nanotechnology (NCN) is a National Science Foundation (NSF) infrastructure and research network established in September 2002. Our mission is to support the National Nanotechnology Initiative (NNI) by creating and operating an ever-evolving cyber platform for sharing simulation and education resources [1]. Our mission is embodied in nanoHUB.org and driven by pioneering research, education, outreach, and support for the nanotechnology community formation and growth [2]. Our early experimentation with online simulation for the nanotechnology community has turned into a robust, production-level infrastructure used by a global community. From an initial user base of about 1,000 users, nanoHUB.org has grown to support over 250,000 users annually. For the 12-month period ending March 31, 2013, nanoHUB.org supported 257,193 users in 172 countries with materials for research and education. Of those users, 12,769 ran 419,839 simulation jobs using 260 different simulation tools [3]. Over 1,000 citations in the literature show evidence of research usage, and over 19,000 students identified in over 1000 formal classes at 189 institutions are evidence of the site's direct use in education. In 6 years of tracking the availability of all functionality on the site, nanoHUB full uptime exceeds 99% with ongoing efforts to improve on this availability.

It is well documented in scientific literature that online communities require fresh and innovative content to grow. Therefore, once this thriving infrastructure went mainstream, keeping it current with relevant and quality content became a parallel goal. With support from industrial partners, a team of Purdue University faculty and students has developed a new approach to provide a conceptual and computational pedagogical framework for applications of nanoelectronics. This framework attempts to tackle challenges in information processing and storage, energy, the environment, and health care technologies. These "Electronics from the Bottom Up" summer schools have been conducted annually at Purdue and then freely distributed through nanoHUB.org. The team is led by Mark Lundstrom, Purdue's Scifres Distinguished Professor of Electrical and Computer Engineering; Supriyo Datta, the Thomas Duncan Distinguished Professor of Electrical and Computer Engineering; and Ashraf Alam, Professor of Electrical and Computer Engineering. Intel Corporation and Purdue University have a long history of collaboration and cooperation that enabled the curriculum for "Electronics from the Bottom Up" to be created.

Parallel to this new educational focus for approaching nanoelectronics learning was the growing realization that a new paradigm for workforce readiness was needed in the nanotechnology space. While there is significant movement on Massively Open, Online Courses (MOOCs), our team realized that tackling high quality workforce ready content was a slightly different problem requiring a completely revamped format and approach to teaching advanced concepts in nanotechnology. Our team has, therefore, adapted the bottom up approach to be offered in a shortened online course that is broken up into 5 week modules. All this innovative content is now being presented through a new experimental platform and curriculum partnership known as nanoHUB-U.

II. Background

A. Impetus for nanoHUB-U and Course Content Format

The 21st Century is the era of nanotechnology and multidisciplinary research. It can be impractical and time-consuming to acquire all the skills and knowledge needed through semester-long university courses. Students need breadth, and working engineers need to learn new topics. But traditional courses usually assume a background in the field, and therefore require a long string of prerequisites. The nanoHUB-U curriculum addresses the need for a set of short, workforce ready course modules that are rigorous and thorough but are also cutting-edge and specifically designed for a broad audience of engineers and applied scientists. The unique aspects of the nanoHUB-U curriculum are:

1. Original content not yet available in textbooks (driven by cutting edge research).
2. Content organized into new, short, self-contained modules with quizzes, homework, and forums.
3. Designed for broad accessibility without a long list of prerequisites.
4. Seamlessly integrated with simulation tool(s) where appropriate.
5. Taught by outstanding instructors who are also leading researchers.
6. Delivered through the powerful nanoHUB/HUBzero platform.

nanoHUB-U also provides a broad understanding of fundamentals as well as introductions to new developments in materials, devices, and systems.

After deciding to venture into this new space, the team had to decide what format would best suit the intended audience. The “Electronics from the Bottom Up” course set was offered as a live summer short course at Purdue with nanoHUB.org hosting the resources and simulation tools. While this became a valuable learning experience for many, extending the reach of this content became essential. Conversely, there are thousands of courses on nanoHUB that are openly accessed by a multitude of users. However, a lack of formal course structure and feedback loop made the assessment of learning outcomes difficult. It quickly became clear that nanoHUB-U would experiment with a blended learning approach with both self paced and collaborative, in pace options to best serve the most learners [4].

With the advent of the massive open online course (MOOC), the typical length of 50 minutes for a lecture is being challenged. Do typical learners have the mental stamina to not only listen to complicated technical material but also retain it for future evaluation? Recent studies on module length show that while there is no difference in student retention for modules of different lengths, learners do find shorter modules more attractive and are more optimistic that they will complete them [5]. With this in mind, the nanoHUB-U team decided that the courses would be made up of shorter than the typical lectures.

Overall the basic format of a nanoHUB-U course is:

- 5 week course
- 6 lectures per week (15 – 20 minutes each)
- 1 quiz per lecture (multiple choice with answers provided)
- 1 homework assignment per lecture (multiple choice with solutions provided)
- 1 exam per week (multiple choice, only score provided)
- 1 exam retake per week (multiple choice, only score provided)

All of the nanoHUB-U courses have been videotaped and the instructors spend a lot of time in post production - synching up the audio and merging together the slide presentation with the professor’s in person lecture. Some of our instructors are also now using these lectures for on-campus classes in the flipped mode where these video lectures are a substitute for traditional live lectures and the feedback from students has been quite encouraging.

Another strength of using an easily-accessed, web-based platform is that all materials are offered in a multitude of formats hosted through nanoHUB-U and also through YouTube to ensure the learner has the network bandwidth required to obtain the materials. All of these aspects lead to a high-quality product and highly enhanced learning experience. Another area of significant importance is that all of these materials are naturally instrumented to understand various measures of learning. Over the next few months, nanoHUB-U will be undertaking a series of learning analytics work that can shed light into how people learn advanced nanotechnology concepts using these new platforms.

B. Supporting Tools and Applications

While the content and its production have been the most important pieces of the nanoHUB-U environment, there are also several supporting tools that make the experience complete. nanoHUB currently hosts over 260 simulation tools online. Those tools are used wherever possible to enhance the learning experience for the nanoHUB-U learner. For example, the atomic force microscopy course on nanoHUB-U used a simulation tool called VEDA (virtual environment for dynamic AFM) that provides a deeper quantitative understanding of the theory and physics behind dynamic atomic force microscopy (dAFM). Through February 2013, VEDA has been used by over 1300 users in over 14,000 simulation runs [6].

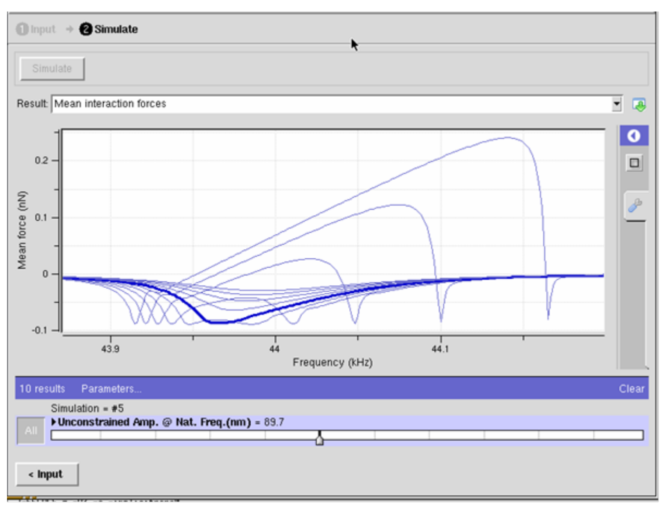

Figure 1: Screenshot from VEDA simulation

Another supporting tool in the nanoHUB-U umbrella enables a social-media like environment to create a collaborative classroom. This tool, called Hotseat [7], is embedded into nanoHUB-U and provides a discussion forum for the course. The students post comments (from the course itself or from other social media sites) and during the in pace portion of the courses, the professor or graduate student respond to the most popular student questions. Students are also able to respond to the questions posed by others allowing for an even greater support structure. Hotseat is a product that was developed at Purdue in the central IT organization to support collaborative learning on campus and beyond [7].

The final supporting tool that supports this innovative learning environment is relatively new to the Purdue learning space. Once those in the course have completed and achieved a passing grade, the initial procedure was to send them a certificate of completion. At the same time a reward system was being discussed, the Purdue central IT organization was building an electronic badge awarding application called Passport that integrates into the Mozilla Backpack system. Badges awarded to students are designed for each individual nano area and are linked to the specific learning objectives of the nanoHUB-U course. The goal is that these badges will carry value for not only the recipient but that they may eventually indicate a learned skill value to whomever is presented the badge [8,9].

This nanoHUB-U course platform has been built as a best of breed tool environment offering the richest available experience for both faculty and learners. The entire environment is designed with advanced (as well as novice) learners in mind. The content format and the workforce ready nature of nanoHUB-U courses clearly distinguish it from other MOOCs.

III. Case Study Data Results

The first course set offered in the nanoHUB-U format was taught by Professor Supriyo Datta and was called the Fundamentals of Nanoelectronics. Professor Datta developed two web-based courses in response to enthusiastic feedback received for his video lectures posted on nanoHUB, which have attracted over 75,000 viewers since 2004. The content of the two courses has been refined and condensed from the original 30 weeks of course material delivered in two semesters at Purdue University into two five-week nanoHUB-U courses. This course set was offered beginning in January 2012 and the enrollment reached 950 students worldwide. The interesting thing to note about these courses is not the enrollment numbers, but the completion numbers. Over 35% of the students enrolled in this course completed it. The team attributes the higher than normal completion percentages for these non credit online courses to the small fee charged for entry to the course and to the ability of Professor Datta to teach high level complicated concepts in simple forms.

Fig. 2 shows the organization type of the registrants for both courses offered by Professor Datta. While it is expected that the largest group of registrants would be graduate students (41%), it is interesting to note that the second largest group is from industry, making up 15% of the class. It is also worth noting that the nanoHUB-U team considered themselves catering to working engineers and graduate students, yet 10% of the registrants list themselves as university undergraduate students.

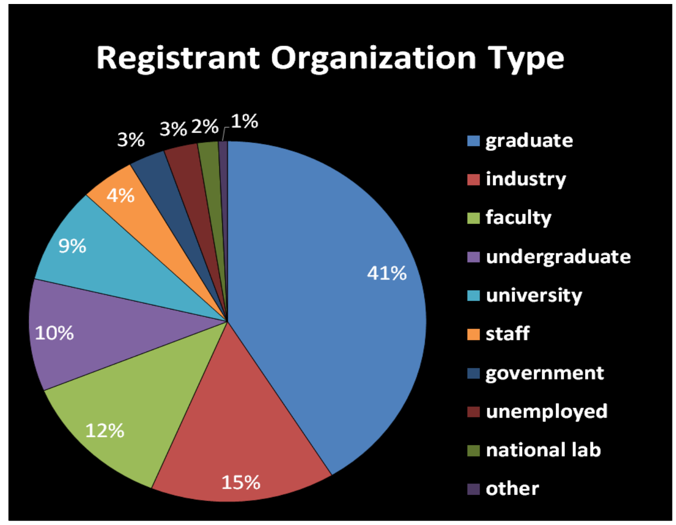

Figure 2 Fundamentals of Nanoelectronics Course Registrants by Organization Type

The registrants for these two courses also represent 64 countries across the world. The largest group came from the United States with just over 28% of the total registrants. The second largest source of students was from India with just over 24%. No other single country made up a significant portion of the registrants for these courses.

Once the course was completed, all students (even if they were not able to complete the course) were sent a post-course survey. Of the 950 students signed up for the course, 93 started the survey. That is a response rate of about 10%. Of those that started the survey, 81 of them completed an exercise to rank the major course artifacts by how useful they were to the course. Fig. 3 shows the results of that ranking. It is clear that the students find the video lectures to be the most useful learning artifact of the course. Almost 93% of them ranked the videos as the most important item for the course. It is also clear that the discussion forum (Hotseat) is the least useful course artifact as selected by over 55% of the course registrants. Quizzes and exams also seemed to be ranked as less useful than other artifacts. It could be that testing learning of complicated material using relatively simplistic multiple choice quizzes and exams does not enhance the learning experience for the student significantly.

While the post-course survey was intended to be the best method for assessing the course over the entire group of registrants, the system that awarded the badges (Passport) also provided an opportunity to ask a few questions before the student could pick up their badge. This opportunity was limited to only those that passed the course and therefore earned a badge - around 336 students. While the entire idea of awarding a badge is relatively new and was not advertised well, it is interesting to note that 98 of the students that passed the course (almost 30%) picked up their badge and completed the short survey. These short questions again told us that over 83% of the students enjoyed the video lectures most. The students provided feedback showing that the discussion forum (30%) and the fast pace of the course (24%) were the least popular.

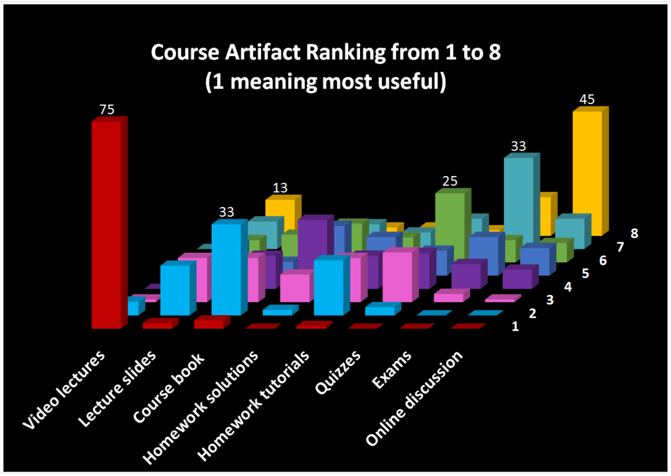

Figure 3: Course artifacts ranked by usefulness

IV. Future Work

For the nanoHUB-U team, this has been a great experiment adopting and evolving the use of the existing nanoHUB platform to offer a new line of courses, both with a new format, a certificate, and a badge reward system. There are many more experiments to consider and questions to be answered. For example,

- Will the courses be as valuable with a lower touch production system?
- Can the courses be bundled or packaged in an ala carte fashion to meet requirements for a degree both at Purdue and at other institutions?
- Is there a potential market for working with industrial partners to create courses that their workforce demands?
- How can non Purdue faculty be engaged in expanding the nanoHUB-U curriculum?

The nanoHUB-U team is striving to answer these questions and explore different avenues to bring fresh, unique nanotechnology related content to the masses.

V. Conclusion

It is clear that the strength in the nanoHUB-U content is derived from its close linkage to research. Using an agile online platform with an already engaged community allows shortening of the time that it takes for proven research to bring value to a classroom, whether "brick and mortar" or "click and mortar." nanoHUB-U has been able to leverage this research to education connection to obtain curriculum that has the most value to those seeking to continue their education. This will always be the driving force behind this innovative team.

Here are the current nanoHUB-U course offerings:

- **Fundamentals of Nanoelectronics**
  - **Part 1: Basic Concepts**
  - **Part 2: Quantum Models**
- **Fundamentals of Atomic Force Microscopy, Part 1**
- **Fundamentals of Atomic Force Microscopy, Part 2**
- **Nanoscale Transistors**
- **Thermal Energy at the Nanoscale**
- **From Atoms to Materials: Predictive Theory And Simulations**

Please visit http://nanoHUB.org/groups/u for more information.

Acknowledgment

Michael McLennan created the Rappture Toolkit and Rick Kennel wrote the scalable middle ware of HUBzero that, respectively, enable and power interactive nanoHUB simulations. The Network for Computational Nanotechnology (NCN) manages nanoHUB.org and is funded by NSF Awards # EEC-0228390, 0634750, and 1227110. The Nano-Engineered Electronic Device Simulation (NEEDS) node of the NCN funded by NSF award # EEC-1227020 spearheads the nanoHUB-U curriculum development efforts.

References

[1] Klimeck G, McLennan M, Brophy SB, Adams GB III, Lundstrom MS. nanoHUB.org: advancing education and research in nanotechnology. IEEE Computers in Engineering and Science (CISE), 2008, 10, 17–23, doi:10.1109/MCSE.2008.120.
[2] Strachan A, Klimeck G, Lundstrom MS. Cyber-enabled simulations in nanoscale science and engineering. Comput. Sci. Eng. 2010, 12, 12–17, doi: 10.1109/MCSE.2010.38.
[3] nanoHUB usage website: http://nanohub.org/usage/overview/
[4] Singh, H. (2003). Building effective blended learning programs. EDUCATIONAL TECHNOLOGY-SADDLE BROOK THEN ENGLEWOOD CLIFFS NJ-, 43(6), 51-54.
[5] Cristina Pomales-García & Yili Liu (2006): Web-Based DistanceLearning Technology: The Impacts of Web Module Length and Format, American Journal of Distance Education, 20:3, 163-179
[6] nanoHUB VEDA usage website:https://nanohub.org/resources/veda/usage
[7] https://news.uns.purdue.edu/x/2009b/091102BowenHotseat.doc.html
[8] http://www.purdue.edu/newsroom/releases/2012/Q3/digital-badges-show-students-skills-along-with-degree.html
[9] http://www.nytimes.com/2012/11/04/education/edlife/show-me-your-badge.html?_r=2&