San Francisco's New Start-Up is Reengineering Engineering Education

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Silicon Valley's New Start-Up is Re-Engineering Data Science Education

Introduction

Nine out of ten jobs that didn't exist ten years ago require engineering skills. From app developer and data scientist, to user experience designer and crowd funder, to Maker Space manager and biohacker, most of today's highly coveted positions demand a particular brand of expertise, one that enables us to engineer solutions to complex problems in multiple fields.

At present, most engineering higher education programs typically do not offer students the opportunity to develop skills across multiple disciplines. They focus on theory in a single discipline and generally do poorly in bridging the disconnect between education and industry interests. These programs fail to engage 21st century learners, ignoring the plethora of resources and techniques made available by advanced technology.[1]

GalvanizeU offers programs that are industry relevant. Developed in partnership with the University of New Haven (UNH), GalvanizeU's data science program is based in Silicon Valley, California (San Francisco). GalvanizeU/UNH will infuse a new breed of diverse, creative and interdisciplinary talent into the field of data science.

This paper describes the innovative way in which GalvanizeU/UNH's curriculum is designed to address the needs of students, educators, employers, and stakeholders, combining learner-centered pedagogy, industry partnerships, and a commitment to continuous improvement. The first program – an M.S. in Data Science – has been approved both by the Office of Higher Education in Connecticut and the Bureau for Private Postsecondary Education in California and launched in March 2015. Details of the GalvanizeU/UNH program as well as the key performance indicators to measure institutional and learning outcomes evaluation are also described.

GalvanizeU/UNH's Vision, Mission and Values

Mission: Educate industry focused world-class data scientists, equipped to attain full employability, through a constructivist learning environment that revolutionizes how students think and feel about technical education.

Vision: Train a new class of industry focused data scientists prepared with the experience necessary to succeed in an industry setting.

Overarching Strategies: The goal of the MS in Data Science program is to prepare data scientists who are intimately familiar with industry needs and can produce useful information from the massive amounts of data available in a variety of fields, such as financial services, health care, education and marketing. The goal will be accomplished by pursuing the following strategies:

1. Understanding the needs of our stakeholders and defining the desired competencies of our graduates (knowledge, skills and values) to develop degrees, certificates and other learning experiences taking into consideration how people learn.
2. Developing master's degrees in areas at the intersection of industry needs to generate employability and student interest.

3. Developing innovative and fun learning spaces and experiences for students (and faculty) to gain knowledge, practice skills and develop institutional values.
4. Implementing a continuous quality improvement culture, and assessing outcomes to grow and expand.
5. Drawing students capable and interested in completing an engineering degree, particularly underrepresented minorities and women who, for a multitude of reasons unrelated to skill and ability, are choosing other paths.
6. Offering a learning experience that is more engaging and responsive to student learning styles (mix of learning resources and modes), employer-relevant and practical (project-based learning) than traditional engineering programs at a lower price point.
7. Employing faculty who are a smart blend of engineers + educators, who explore innovative teaching, and are mentors.

The GalvanizeU/UNH Academic Model and Pedagogy

GalvanizeU/UNH's program places hands-on, collaborative, project-based learning at the center of education. Emphasizing real world experience, communication, leadership and entrepreneurship, it offers a diverse body of students the opportunity to experience data science as an engaging and collaborative profession, pairing technical training with 21st century professional skills.

A priority goal of GalvanizeU/UNH is to attract a more diverse student body. At present, engineering in Western countries is an overwhelmingly male-dominated field. GalvanizeU/UNH aims to help reverse this trend, as well as support a greater number of students from different backgrounds, by offering scholarships from partner organizations with similar goals.

Another of GalvanizeU/UNH's core goals is to create a new path for how data science education is perceived and taught. To train a new class of data scientists, educators must emphasize problem solving and design thinking over tools and technology. Its curriculum model features needs/competency-based, learner-centric and project-based instructional strategies, and includes opportunities for industry partnerships and continuous development, as explained below.

Needs/competency-based.[2] GalvanizeU/UNH is developing curricula based on the needs of industry. Competencies are defined as the sum of the knowledge, skills and attitudes/values students should have by the time they complete the program.

Learner-centric.[3,4] GalvanizeU/UNH facilitates opportunities for students to acquire skills through their preferred learning styles (alone or in teams, passive or active, verbal or visual, systemic or in sequence). All students and instructors complete Felder's Learning Styles Inventory (LSI) test and learning experiences are designed to incorporate the results. Daniel Goleman's Emotional Quotient (EQ) test also provides students with the assessment of their professional skills and suggestions for improvement. The tests are given at the beginning and end of programs.

Project-based learning.[5] Courses in GalvanizeU/UNH programs focus on preparing students through projects that can be applied to address real-world industry or public sector needs. GalvanizeU/UNH ensures not only that industry projects are available through its corporate partners, but also that they motivate and address the needs and career goals of a diverse student body. Data science thesis projects, for instance, would address a wide variety of issues at

multiple levels, including education (local), health services (national) and climate and transportation (global).

Industry partnerships.[6] Industry partners are essential for developing competency-based curricula. GalvanizeU/UNH is engaged with industry in various ways: in establishing competencies for its programs, in developing course material, in teaching and in providing mentorships, and internships for students and faculty.

Continuous improvement.[7] Excellence is achieved through continuous assessment, evaluation and development. GalvanizeU/UNH is committed to performance, quality, accountability and transparency. GalvanizeU/UNH's faculty recognize that institutional performance measurement is key to the strategic management of its resources and to rigorous planning for its future. Data and information gathered at GalvanizeU/UNH is therefore key to its mission. A series of key performance measures that provide data by which GalvanizeU/UNH can measure the health of its overall institutional system have been carefully chosen to monitor institutional activity. These measures provide an accountability framework that will help GalvanizeU/UNH improve, keep internal and external stakeholders informed, and develop models for strategic planning and decision-making (e.g., curriculum improvement, enrollment planning and analysis).

Finally, the GalvanizeU/UNH model includes the development of "conscientious leadership and active entrepreneurism." All GalvanizeU/UNH programs will require a Leadership and Entrepreneurism course, focused on developing professional skills and attitudes needed in the practice of engineering (e.g., teamwork, communication, ethics, inclusiveness and diversity, new ideas/business development). The development of these professional skills are also integrated into all courses within the curriculum.

Curriculum Design Approach

We are using a combination of instructional systems and the "Backwards Approach (BA)" to design GalvanizeU/UNH curricula. As a field, instructional design is historically and traditionally rooted in cognitive and behavioral psychology, though recently constructivism (learning theory) has influenced thinking in the field. Instructional Systems Design (ISD) or simply instructional design[8] is the practice of creating "instructional experiences which make the acquisition of knowledge and skill more efficient, effective, and appealing".[9] Thus, ISD focuses on the learning experience. The process consists broadly of determining the needs of the learner, defining the end goal of instruction, and creating some "intervention" (the "catalytic process") to assist in the transition, and thus, resulting in learning. Ideally the process is informed by pedagogical (youth oriented) and andragogical (adult oriented) learning theories and may take place in student-only, teacher-led or community-based settings. There are many instructional design models. Many involve five basic phases: analysis, design, development, implementation, and evaluation. This instructional design approach is like engineering problem solving.

BA design[10,11] is a method of designing curriculum by choosing learning outcomes before instructional methods or assessments. This means one chooses the outcome of the learning experience first, and let that guide the teaching/learning and the assessment/evaluation. This method challenges "traditional" methods of curriculum planning in which a list of content that is to be taught is created and/or selected first and teaching/assessment methodology usually are lectures and laboratories, with written exams as assessment of learning. In backward design, the educator starts with goals, creates or plans out assessments and finally makes lesson plans. Supporters of backward design liken the process to using a "roadmap".[12] In this case, the destination is chosen first and then the roadmap is used to plan the trip to the desired destination.

In contrast, traditional curriculum planning has no formal destination identified before the journey begins. One might argue that BA design is implicit when once teaches from a textbook, because textbook authors perhaps write the book after first developing learning outcomes. This may not actually be true; many authors, like many traditional instructors, write books according to a list of topics and not necessarily to achieve learning outcomes. Further, in the data science area, standard textbooks are yet to evolve, and instructors must develop teaching materials from a variety of references. BA design becomes especially relevant in this context.

In BA the educator is able to focus on addressing what the students need to learn, what data can be collected to show that the students have learned and how to ensure the students will learn. Below is a brief description of GalvanizeU/UNH's curriculum design phases:

Analysis – Understand industry needs in the Data Science field, technology trends, and employer needs. The engineering/technology competencies for GalvanizeU/UNH's data science program were captured through several ways, including industry representatives, institutional and program accreditation requirements and by benchmarking successful programs worldwide. The competencies for our first program described later in this paper, include a combination of data science knowledge, skills, and attitudes/values.

Design – Led by the Director and the Instructional Designer, started by distributing the competencies across the curriculum ("roadmap") as shown in Table 1, and establishing the desired depth of learning the competency (scale of 1 to 5). With the assistance of academic and industry experts, more specific learning objectives and desired outcomes were written for each of the individual courses. The course syllabi include specific learning objectives and outcomes, weekly course plan, weekly learning experiences, and outcomes assessment for all the competencies assigned to the course, as well as traditional information like title, description, textbooks/references and other logistics. We are using the Felder-Brent definition of learning objectives (or instructional objective*): "A statement of something observable and clear that students should be able to do after receiving instruction, plus (optional) conditions under which they would do it and/or what would constitute acceptable performance."* [13]

Development – Teams of two to three subject matter experts with academic and industry experience are currently tackling the task of developing each course. This entails: defining topics and learning outcomes, identifying resources needed, and creating active learning experiences and assessments. Research shows that students learn better when they know why/what they are learning, when they see applications on how the knowledge is used, when given time to think and share thoughts with others, and when they engage in active learning. Thus, to design the learning experience we have asked course designers to answer the following questions:

- How will students learn?
- How do we best prepare them for industry practice?
- What resources are needed?
- When and where will the learning take place?
- Who is responsible?
- What experiences will help students learn the knowledge and develop the skills, attitudes and values?
- How can we address different learning styles?

Table 1. Curriculum Learning Outcomes Roadmap

Learning Outcomes	Outcome 1 - Educate and Ise Data Science Systems	Outcome 2 - Design solutions to Data Science Challenges	Outcome 3 - Work in multi disciplinary, multi-stakeholder, teams	Outcome 4 - Communicate effectively with multiple stakeholders	Outcome 5 - Leverage and influence professional networks	Outcome 6 - Apply security and ethical standards	Outcome 7 Manage Project delivery effectively	Outcome 8 - Respect Diversity	Ouctcome 9 - Be Flexable and adaptive
Introduction to Data Technologies	3	-	1	1	1	1	-	1	1
Data Leadership and Enterperneurism	3	1	3	3	3	3	3	3	3
Data Infrastructure 1	5	5	1	1	1	3	1	1	1
Data Infrastructure 1	5	5	1	1	1	3	1	1	1
Machine Learning and Analytsis 1	5	5	1	1	1	3	1	1	1
Machine Learnining and Analysis 2	5	5	1	1	1	5	1	1	1
Data Stewardship	3 to 5	3 to 5	1	1	1	3	1	1	1
Data Elective	3 to 5	3 to 5	1	1	1	3	1	1	1
Data Industry Practicum	5	5	1	1	1	3	1	1	1
Data Capstone Project	5	5	1	1	1	5	1	1	1

The teaching/learning strategy is dictated by the course objectives, should balance facts with concepts, and include a variety of delivery modes. Therefore, all courses have a blended mix of, for example, short lectures with active "in class lab" exercises that keep students alert, engaged and motivated in the learning process. Proposals are being leveraged from experts in industry and academia to develop laboratory/active learning experiences to support the program. All courses include learning objectives and outcomes assessment (see section below for more details).

One important element in GalvanizeU/UNH's program model is the space/environment where student learning takes place in a constructivist manner, and where students interact with faculty, industry collaborators, and other students. GalvanizeU/UNH's campus is located within Galvanize's facilities in San Francisco. Galvanize is a company focused on coalescing communities of technology startups and larger enterprise partners by providing an integrated entrepreneurial workspace. Students are integrated into their creative and collaborative environment, engaged with data science projects in companies and undergo practicum experiences. In many ways, the environment and pedagogical approach resemble studio-based instruction.[14,15]

Figure 1. GalvanizeU/UNH's creative environment

The learning environment is learner-centric, promoting learning by doing as well as self-learning. GalvanizeU/UNH's faculty and teaching assistants serve as mentors and catalyze learning in a fun and motivating environment.

The learner-centric and constructivist learning environment are promoted by the following practices:

- GalvanizeU/UNH's practice based format allows students to experience data science problem solving and design skills, including problem definition, identification of possible solution/design roadmaps, selection of best alternative based on real-life constraints and customer needs — all of which are constructivist in nature.
- Constructivism promotes hands-on learning. Thus, in addition to having traditional classrooms for lectures, GalvanizeU/UNH has multiple places (including labs and

computer workstations) where students can experiment and work on their class and capstone projects, meet in teams to discuss their work, reflect on issues, meet with industry representatives, meet with faculty informally, etc.

- All students work as part of a community from the beginning. Current industry and/or community challenges are being identified to provide real-life learning experiences.

These carefully selected elements, delivered in an expansive physical environment to create a new breed of engineer—smart, diverse, creative, and passionate about making a difference in the world.

Implementation – GalvanizeU/UNH programs are deployed in a cohort mode. A cohort is a group of students that follows the same set schedule and progresses through the accelerated program together. The intensive scheduling, promotes an interactive learning environment and facilitates networking opportunities and career strengthening relationships. Classes are taken in pairs and held four times a week in an intensive 7.5 "mini-mester" format. The first 2 hours are in a lecture with lab practicum format (facilitated by an instructor). This is followed by two hours of "open lab" hours (mediated by a TA). Attendance at lectures is mandatory. Lecture sessions include hands-on activities, group work, demos, etc.

Students have a total of 120 contact hours over 7.5 weeks — 2 hours of lecture and 6 hours of in-class lab practicum per class each week, plus 12-16 hours of out-of-class work each week. Out-of-class work includes coding and practical application lab work done outside of class times, and and team project work. Students are expected to do both individual and group assignments and there is a mixture of short- and long-term projects. Many activities are due in one week. Group and final projects are typically introduced earlier in the course.

An important component of the GalvanizeU/UNH curriculum is the capstone course where students work in teams to address current, industry-sponsored challenges; a win-win-win for students, GalvanizeU/UNH and industry. These projects provide a unique opportunity for industry sponsors to partner with GalvanizeU/UNH to help educate and mentor the next generation of data scientists while addressing their own company challenges, students to practice the competencies they've learned in class, and faculty to learn and contribute new ideas and network with industry.

Partners and partnerships with industry are key to the GalvanizeU/UNH program. They provide ideas, resources and opportunities to develop content and learning experiences for both students and faculty. They also provide real-life projects for students as well as internships and practicum experiences. Partners who provide projects for teams of students and/or host them for a period of time at their companies become mentors. Their involvement is essential to the success of the GalvanizeU/UNH capstone and internship/practicum courses.

Evaluation – Accountability by governments and society is being requested of higher education more and more. Escalating costs of higher education and attrition rates that are not acceptable are the primary drivers of the need for accountability to society. In August 2013 President Obama unveiled a proposal to make colleges and universities more accountable and affordable by rating them, and, linking federal aid to educational outcomes. Ratings would be based on tuition, graduation rates, debt and earnings of graduates, and the percentage of lower-income students who attend.[16]

With the assistance and support of industry partners, GalvanizeU/UNH is developing a learning analytics platform with a visualization dashboard to learn the status of our institution

and be able to make informed decisions for continuous improvement. A set of key performance indicators (KPI's) has been identified across all functions (academic, administrative, research and service) and the data collection schedule and responsibilities are being established. The learning outcomes assessment strategy is described below.

Learning Outcomes Assessment Strategy

Consistent with the Comprehensive Curriculum Assessment Plan (CCAP) of UNH, the program will be evaluated through an outcomes assessment strategy composed of the following characteristics:

- Internal course assessments, surveys and focus groups (students, faculty, industry)
- External surveys and focus groups (industry partners, Academic Advisory Council, alumni)
- Holistic evaluation (across all dimensions, i.e., student learning, lab facilities, practicum experiences)
- Quantifiable measures (number of students, partners, graduates, freshmen, courses)
- Subjective evaluations (quality of the program and learning experiences)

Course and instructor evaluations by students will be conducted at the conclusion of each course using the same online system used at the UNH main campus.

Learning of content/knowledge in program areas will be assessed through class exams, labs, project work and reflection papers. Professional skills development will be assessed with specific tools/rubrics developed for the program and through student portfolios of projects and other deliverables.

The student learning outcomes and evaluation strategy will include:

- Mapping of learning experiences (courses, practicum, etc.) with program outcomes
- Mapping of assessment tools to learning experiences and those responsible for carrying out the assessment
- Analysis of outcomes assessment data
- Writing of outcomes report

All of the learning outcomes will be assessed through direct measures, for example, through exams, lab reports, projects and papers. In addition, professional skills (such as teamwork, communication, project management, and ethics) will be assessed through indirect methods (surveys, self-assessments, and focus groups). Individual course syllabi list the learning outcomes and assessment tools to be used. All learning outcomes will be assessed from three perspectives: students, faculty and industry. A timeline has been established for the frequency of data collection from each course.

Student and Faculty Profiles

Who will be GalvanizeU/UNH students? We expect a significant proportion of our students to be those who have jobs in Silicon Valley, California and other US states who are developing/diversifying their economies around Data Science. These students are interested in enhancing their professional careers through an accredited degree. We also expect students who are eager to complement their education in an area of engineering/technology of high demand to join us directly after completing their bachelor's degrees. Three incoming cohorts of students

will be accepted each year. In the first year only two cohorts will be accepted; the first cohort of 11 students started on March 23, 2015, and a second cohort will start in August. In the steady state after initial growth, the program is expected to have an annual enrollment of 200 students across all cohorts.

UNH has hired and continues to hire faculty with PhD and MS degrees for both full-time and part-time positions. Full-time faculty positions are non-tenure track and candidates must hold a PhD or MS degree with appropriate work-related experience in computer science, engineering, or a related field. Areas of interest include data science, data engineering, analytics, data visualization, health informatics and related areas. Applicants may come from traditional academic programs or with long-term industry experience. Required qualifications include demonstrated evidence of excellence in industry achievement or development (basic or applied) and teaching, such as through mentorship, strong communication and interpersonal skills and a commitment to collegiality and teamwork. Prior experience working in industry is highly valued. Faculty responsibilities include course design and teaching master's level courses, particularly in Data Science technologies, advising and mentoring highly-qualified master's students; and liaising with industry to refine course work, identifying student project practicum experiences, supervising student capstone projects, and service to the department, college and university. Continuous education or industry practice to learn or augment skill sets is a must. Responsibilities also include serving as a role model and engaged member of the university learning community.

Part-time faculty will mostly be qualified industry people with the experience and desire to make a difference in higher education (i.e., visiting experts), as well as faculty from other universities who wish to spend one or more sessions teaching and mentoring students as Visiting Scholars.

Program Oversight and Hurdles Encountered

The program and new campus in San Francisco described in this paper was not easy to launch. With significant input from industry and faculty consultants from other universities, Dr. Lueny Morell developed the first draft of the program. Subsequently, Dr. Michael Tamir, who had significant experience in data science, was recruited and he restructured the courses significantly. A special committee of four computer science faculty at the main UNH campus was created to provide feedback on the program. The program had be to be approved by various university committees, including the faculty in the Department of Electrical Engineering and Computer Science, the Engineering Graduate Curriculum Committee, and University Graduate Curriculum Committee, the University Budget and Finance Committee, and the Faculty Senate. Finally, the program had to be approved by the Connecticut Office of Higher Education and the California Bureau for Private Postsecondary Education. Difficulties were faced at every stage due to the following reasons:

- The partnership between a for-profit company and a non-profit private university was the first of its kind in the state of Connecticut and all parties were extremely cautious.
- The support staff hired to assist in San Francisco had not previously worked in an accredited higher education environment, and had much to learn with respect to recruitment, admissions, federal financial aid regulations, faculty hiring, etc. Staff at the main campus continues to work closely with the staff in San Francisco.
- The electronic portals supporting student applications and enrollment had to be coordinated between those at the UNH main campus and those at GalvanizeU/UNH.

The computer science faculty, dean of engineering and provost at UNH provide oversight on all faculty hiring, reviews and evaluations.

Conclusion - What Makes GalvanizeU/UNH Unique?

GalvanizeU/UNH is a new, engaging, industry-relevant institution and will provide a practical MS in Data Science program that educates world-class engineers in a constructivist learning environment that revolutionizes how students think and feel about data science education. GalvanizeU/UNH represents:

- A new concept for learning data science – industry connected, collaborative and fun.
- A new breed of educators – pioneers in the field and mentors.
- A new breed of creators – thinkers, innovators and change-agents.
- A new concept for engineering education – a smart blend of learning in a compelling Maker-space.

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