Increasing Diversity in Engineering, IT, and Computer Science

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Abstract – *There is an interest in increasing diversity in traditionally very homogeneous and rather closed professions of engineering, IT, and computer science. The National Science Foundation (NSF), government, corporations, as well as institutions of higher learning all have this issue on their agenda, for various and differing reasons. Although many efforts have been made over the years, these professions are still not diverse enough and numbers of some minorities have even decreased. In this paper we discuss some of the potential barriers to diversity and our approach to overcome them as a female faculty member in a computer science department. Strategies, pitfalls, and successes are presented.*

Keywords: diversity, minority, engineering, IT, computer, science

1 Introduction

There is much discussion about numbers of technical labor force in the U.S. Some organizations, such as IEEE, claim there is no shortage [14]. Some other organizations and industry claim there is a shortage [15]; for example, Senior Vice-President of IBM Technology group advocates active measures to increase the numbers [19]. Industry in general claims there are not enough "good graduates." "In a survey of 2,001 students or recent graduates (18- to 24-year-olds) and 1,000 hiring managers, fewer than two in five hiring managers who had interviewed recent graduates in the past two years found them prepared for a job in their field of study" [20]. Perhaps this data indicates that we do graduate enough students, but with insufficient skills for work in industry.

These questions are very important to consider when attempting to assure a country's economic prosperity and security, for example providing workforce capable of competing in the global market and digitally protecting and defending the country's resources [1] [2]. The U.S. government itself acknowledges a shortage of technical workers, especially in the area of cybersecurity; expresses concern about it; and supports efforts to increase numbers of graduates. Effort to increase understanding of effective undergraduate Science, Technology, Engineering and Mathematics (STEM) education produced analysis of effective practices, directions for future research and suitable evaluation criteria [3] [4].

The consequence of these concerns and efforts is considering populations that traditionally did not supply majority of technical workers: women, minorities, older workers, veterans, and workers with disabilities. Tapping into these resources can increase the numbers as well as the quality of creative input, as these relative "newcomers" change the nature of the field. However, many approaches have been tried previously in engineering-like fields and those fields are still not very diverse. Some numbers are declining, for example the number of bachelor degrees in computer science awarded to women [29]. It is still not clear as to how to achieve the goals. National Science Foundation (NSF) held Engineering Ideas Lab in March 2014, to brainstorm and address these issues [1].

Facing diversity might be necessary in situations where formerly underrepresented groups become the majority. Some states have predominantly minority populations. For example, in Texas in 2012, "more than 55% of population was of race other than non-Hispanic white" [18].

In states where diversity is not as pronounced, facing diversity may not be an urgent topic at many institutions of higher learning. However, learning institutions are typically interested in increasing numbers of students and thus increasing tuition revenue, which can lead to a willingness to tap into new markets. In addition, relatively recent availability of grant money for improving STEM education is a motivator for higher-level institutions to put effort towards such goals. Currently, there are no incentives for faculty to spend any time on valuing and increasing diversity in their classes. One important research issue is to devise structural changes and administrative incentives, e.g. tenure and promotion criteria, that values diversity [25].

Even if underrepresented groups are enticed to join STEM fields, the question remains how to keep them engaged and graduating successfully. What are the barriers to entering the field, retention, and professional success?

In this paper we outline several measures that we use in our own classrooms to mitigate these issues. We have experience teaching in Hawai'i for the last 10 years in public and private universities and community colleges, to students of varying ages and socio-economic backgrounds, in a very diverse population including many Native people.

2 Generation I

One of the prime targets for recruiting into STEM and thus increasing numbers and diversity is the younger generation. There are several terms for people who have never known a world without computers and cell phones. Common terms are "Millennials," "Generation I," or "Generation Z," grouping all people born in the Age of Information, approximately starting in 1980s and late 1990s, respectively. "I" stands for "Information Age" and "Internet," which is the daily staple of Generation I; "me" and "one" as indicated by spending a lot of time on computers and less in social interactions [12].

New generations in the U.S. have certain preferences about studying. They do not feel strongly about studying STEM fields. Nationally, when high students are asked why they do not want to study STEM fields, they complain that such fields are "boring" [5]; that students often do not know adults who work in STEM field and if they do meet any, such adults seem "one-dimensional nerds," and that "students do not know how to work in teams" [27]. The picture is even worse for minorities such as women and students from various underrepresented backgrounds [7]. Another barrier is lack of mathematical and scientific training in American K-12 education; the U.S. ranks low in mathematics and reading, ranking 23-29 out of 34 developed countries, as summarized in [8] using data of the PISA global assessment of students [9] and the latest PISA 2012 assessment [10].

Traditionally, much of STEM education was predominantly lecture-based, but students today do not like lectures. Students are enthusiastic about hands-on classes and activities and working in "fun" teams. Active learning classes, discovery-based laboratories and course-based research provide personal experience that makes theoretical concepts clearer as well as skills for employment and future education [2]. Students also need to feel as a part of the STEM community and capable of working in teams. These practices are core components in traditional Native education. Hawai'i is a highly diverse area where many different groups successfully work together, and it has much to offer in terms of success in working together.

Underrepresented groups have their own particular needs. For example, the unique need of female workers is pregnancy leave. All underrepresented groups need visible and socially endorsed role models. For example, President Obama is a great inspiration for many African Americans, many children now think it is common to see an African American in a position of power.

3 Creating Community; Networking

Students are more likely to succeed if they feel a sense of belonging to their "community." The community provides the practical support and social niche necessary to withstand the demands of academic life. The community for college students is their peers in classroom, as well as their instructors. During the very first class of the semester, we spend about 10-15 minutes, depending on class size, introducing each other – our name, major/year, our goals. Students are then asked to spend five minutes and introduce themselves to one person they did not know before class. In reality, this step takes about ten minutes, until the enthusiastic chatter starts calming down. If a student came to class with "friends" and is sitting next to them, they will have to get up and move to another location in the room to meet new people. Very often, we have a "quiz on names". In some classes, we ask students to introduce each other. This very simple gesture leads to more comfort in the classroom and more collaboration, inside and outside of classroom. We do many activities in teams during class. We also tell the students to choose their study partners and to study in groups. This initial introduction helps break the ice and bond the students.

Another fine point in "belonging" is sense of importance to the community, of oneself and others; and sense of tangible and practical need to create and maintain a functioning community. After the students finish introducing themselves, we ask: "Why is it important that students know each other?" Sometimes students answer: "Because we are competition to each other." Very seldom a student will answer that students are resources for each other. Such entrepreneurial way of looking into one's peers typically has to be introduced. We tell the students that they are business connections to each other from now on; that "many good things" can result from peer collaboration. Everyone knows that jobs, projects and many other resources come from human networks, however, younger students from middle- and low-income families typically need to be reminded that this model holds valid for students as well. We suspect that students do not think of themselves as "grownups" and "business people" and need to be encouraged to build that self-image. We also tell students that their success and networking is important to the institution, since we will be tapping into their success via donation drives, placement of graduates, alumni relations, and other venues.

Another message given to students is that they should observe each other in class and be aware who they want to work with and who they do not want to work with. This measure ensures that all students are on their best behavior and trying their best to succeed in class. This is important to students as they will be doing many projects in teams, and they pick their teammates. Belonging to a team greatly increases retention.

The instructor helps to maintain this sense of belonging by remembering students' names and details about their lives and academic progress and interests. For example, a student with potential problems at home or work (for example, sick family members, plumbing issues, deadlines at work) is allowed to have their cell phone ring during class (as long as they take it and go outside of the room). A student with particular interests can be alerted when something relevant is happening in that field. In general, all students are alerted to and discuss in class events of major importance for the field, such as Heartbleed virus outbreak.

Another venue for increasing the bond of the community is offered via various campus organizations and clubs, as well as other venues for professional networking. Students are encouraged to establish technical or social clubs on campus as well as to join various professional organizations. One incentive for joining is the prospect of employment. Another benefit is a more interesting social life, higher learning, and more collaboration with classmates and instructors. Working together through trials of programming competitions or organizing events bonds students. As the long-term adviser for the Computer Club, we found it challenging and rewarding to stand by and let the students govern themselves, learning in the process about diversity, team work and appreciating underrepresented groups. The last two presidents of the club were female, and the club was more active than before.

4 Collaboration and Co-Creation

Traditionally, engineering education started in military schools. U.S. Army Engineer School was the first engineering program in the U.S. [16]. In 1898, Norwich University was designated, "The Military College of the State of Vermont" by the Vermont Legislature, and in 1907 Electrical Engineering Department was established [17]. The historic legacy of these facts is that approach used in engineering education is similar to that used for soldiers: obedience, control over body and mind, and top-down approach. There is no sense of equality and collaboration between different "layers" in this hierarchical model. Many Native populations, such as African, as well as women, prefer to work in rather egalitarian groups and co-create together. Team work involves co-creation, but not necessarily in egalitarian terms. Some societies, such as many Asian societies, are experts in team work but not egalitarian co-creation.

An egalitarian co-creative process involving team work does not necessarily proceed naturally in the U.S. and often has to be worked on with perseverance. First, the U.S. culture is geared towards individualism; second, it values authority yet on the other hand finds pleasure in teenage rebelling against authority, thus propagating "underdog" versus "upperdog" mentality and preventing increased productivity.

We observe that students like to view themselves as important, as is common for Generation I and in entitled environments. It is important to honor that. We give students choices: when is the homework due, what they would like to work on, what their project will be. We believe that it is very important to teach them to govern themselves because it leads to greater success in technical fields and opens the door to management and business careers. Technical work is usually done in teams and requires communication, negotiation, and self-governance skills. Excellence in these skills is required both for professional and social success, since they are considered socially desirable opposite of "nerdy" behavior and a coveted sign of leadership and business success.

Increased self-governance is intended to increase self-responsibility, which may not be clear to students until they envision the end product of this approach. The balance has to be maintained: although students have a voice, and a very important voice, they have less experience than the instructor and should respect and listen to the instructor. This can be a challenging task in the environments where students feel entitled to form self-governance in the direction of increased lack of responsibility. This behavior indicates that students do not have clear ideas about their professional future. The instructor's challenge is to stay in charge of the class and keep the class focused during co-creative process, for example by repeatedly presenting the grand picture and motivating with examples of real-life benefits. Students themselves can be excellent sources of affirmative evidence encountered in their interviews, internships, and jobs. (It is possible that a student has more experience than the instructor, if the student is an adult learner who has been in the field for many years and is in class simply "to get a diploma;" in which case the student assumes a more active role in the classroom.)

In our experience, students are used to top-down approach, which is based on a subtle fear of the instructor as "someone who can hurt you," e.g. give a lower grade or publicly shame you. In our society, "power" seems to be measured by how much we can hurt others. However, this approach may not lead to greatest productivity and creativity. The alternative of peaceful cooperation based on accomplishing common goals (e.g. learning class material) seems more appropriate, efficient and productive. Working on commonly agreed goals increases self-motivation and thus speeds up and eases the process.

The fine line between collaboration and top-down approach can be very difficult to maintain, as students typically simply do not have experience in shared governance. In our experience, students themselves can be invested in the top-down model. If the instructor is not "on the top," the students may try to take that role. If the administration supports the students in anything they do, the instructor has to be resourceful to avoid repercussions yet teach students about increased self-responsibility. The other end of this problem is seen in large institutions where students are simply "a number" left to the mercy of the instructor. On this end of the spectrum, students may need to be taught to represent themselves with confidence. In any case, students are taught the lesson that "great power assumes great responsibility."

5 Incentives and Rewards

Traditionally, STEM education is quite rigid in prescribed learning materials. For example, every computer science major has to take calculus, although they may never use it again. Native educational practices are very different. In Native teaching, students choose what subject they want to study, and are taught only if they express interest and dedication. The subsequent training is very hands-on, real-life.

It is my belief that the self-selective and quickly meaningful Native approach can lead to better results with all students, and especially underrepresented populations. The first step is to motivate the students. Students are typically not aware of careers in STEM and their paying potential. Introducing videos, images, slides, and guest speakers makes classes more relevant, interesting, and inspiring. Students do appreciate prospects of higher income and "interesting" careers and typically self-select to work harder to achieve it. They are motivated by tangible goals and real-life examples.

Choosing the right rewards is very important, as rewards are highly motivational. In traditional STEM education, rewards came as "passing the test" which often consisted of memorizing facts. Memorization is considered boring and not creative. Today, problem solving and creativity are expected. In Native educational practices, rewards also required passing some "tests." For example, Native American children in the Plains tribes were quizzed on their bow and arrow prowess by having their food hanging high in a tree on a thin string. In order to eat, the child had to be able to shoot the arrow precisely to severe the string. Current U.S. generations, used to words of praise even if they are failing, would find such tests too harsh and thus require new reward strategies.

Native learning often involves lessons designed to produce failure, as failure often brings most insights and learning. Modern U.S. generations tend to feel very badly about "failing" and want to "succeed" and be rewarded at every step, and even at the very first steps. It requires some training to teach skills of self-introspection and the ability to backtrack and rely on basic concepts; to enjoy the learning process and not take it personally as signs of being "less than," which all students can experience and especially underrepresented populations are more prone to. In a paradoxical way, teaching by using "faulty" examples can put all students on equal footing and bond them stronger. we suspect that it is so because it is highly likely that no students have any experience with this approach, and also because it is presented as a "game." For example, giving students a buggy program and asking them to trace it and fix it usually makes students feel empowered.

One of possible rewards is public recognition, belonging to a community, and sense of accomplishment. Since Generation I is about "I," we find it necessary to include some praise. For example, it is very effective to showcase all student homework, but anonymously, and mention good points and bad points about each piece of work, so that nobody feels "lesser" and good students are encouraged. we practice this strategy in beginner programming classes, showing students' code. This illustrates many possible solutions as well and teaches useful technical lessons.

We also like to use the Socratic approach to teach and ask questions in class. It is advisable to ask the class beforehand if they consent to answering questions one after another. Shy students can usually be coaxed to participate with some gentle probing. Some students may prefer to remain silent. Often an older male can be intimidated by a female faculty and choose to save his face by remaining silent. It is important to acknowledge everyone and find ways to entice them to participate in some way.

6 Written, Spoken and Visual Messages

There is certain terminology in STEM fields that undermines diversity. Some of the terminology is openly racist or sexist. For example, "male and female connectors" in electrical engineering; "master and slave servers" in IT; "FAQs" in computer science; and many others. Even in current workplace, there are practices that undermine underrepresented groups, such as lap dancers at Yahoo's hacking conference in 2009. Fortunately, after many complaints, Yahoo publicly apologized; however, the Internet was full of blogs in protest of the apology [13].

It is very important to use the proper language in the classroom. Students are watching their instructors as role models. If we see inappropriate terminology (for example, on a web page shown in class), we mention it and say why it is in inappropriate and what the alternative acceptable terms might be. For example, "master and slave server" should be shunned in favor of "primary and secondary server." We make sure to use appropriate terminology on all of our teaching materials. We also observe that students appreciate pointing out the reasons for changing the terminology. Students do appreciate when their identity is respected.

It is very important not to use any inappropriate expressions or language in the classroom. For example, it can happen that a capable female student answers questions that males did not know how to answer, and their response can be to laugh at the female. This kind of behavior has to be stopped right away, by clearly stating that laughing at others is unacceptable. Also, any offered suggestions that are inappropriate have to be rejected, gently yet firmly. For example, if students are asked to provide an example of clothing, and someone offers "crotch protector," we gently ask for a different and better suggestion, such as a T-shirt.

Visually, it is important to wear appropriate clothing and accessories that convey professionalism and also do not undermine the humanity of the person, and to provide a good role model for everyone. Technical fields have the reputation for being "geeky." There is a negative stereotype associated with geeks, as isolated white males [23]. It is important that the instructor looks like a "normal" person who has a life. For example, female students examine their female instructors, thinking: “Do I want to look like this when I get older? What does it mean to be a female technical professional? Do I have to become “one of the guys” and lose my femininity?” However, there are many different role models for “femininity” and any other flavor of minority “look” that students can choose from. Thus, it is important that the instructors present themselves in a genuine yet professional way, allowing students the space to be themselves as well, within the constraints of professional expectations. For example, Hawai’ian students of both genders may like to wear flowers in their hair, African-American students may like to wear braids, and female students may like to wear visible nail polish.

The stereotypical image of a professor is someone who is serious, business-like, and rather bland; broadly speaking, the society tends to think of professors through the typical stereotype of a “white bearded old guy” i.e. we think of the typical technical stereotype of middle-aged white male. Typically, this image also often involves suit and tie, or khaki pants and a dress shirt with dress shoes. Unfortunately, this image does not accommodate the alternative possibilities, both on the inner and outer planes. Furthermore, “business-like” does not allow for spontaneity, artistic expression, or too much humor, fun and happiness. If we are going to attract students and retain them, it is suggested to change these stereotypical views [22] [24]. We find improv comedy exercises, such as passing an imaginary beach ball to each other in class, an excellent ice breaker, mental refreshment and bonding tool, especially after long periods of intense focus on technical concepts.

7 Valuing Diverse Perspectives

Modern STEM curriculum is typically taught using examples from the Western world. However, there are many other perspectives. For example, the field of ethnomath uses mathematics from various cultures other than Western. For example, African cultures are known for using fractals in daily life, Polynesians navigated with the stars, and Native Americans use elaborate geometry. It is important to introduce such examples, because it gives students validation of their origins and a sense of value, competence and scientific ability. Many examples and references of this approach are shown in [21].

8 Results

In our experience, students can successfully collaborate and co-create in highly diverse environments. In this paper we present various strategies for increasing the sense of bonding in the community, giving students the voice, and achieving teamwork environment in classroom. Our classrooms are highly interactive, where students of all races, genders, ages, and abilities work together. Informal interviews with our colleagues teaching at institutions on the continental U.S. held at the NSF Engineering Ideas Lab in March 2014 indicate that this situation might not be as common as we take it for granted locally. We hope that our experiences can help to advance the cause of diversity. Further research needs to address accomplishing the fine line of co-creation rather than top-down approach, even in “entitled” environments.

9 Conclusions

This paper presents our experiences in valuing and encouraging diversity in our own classrooms. Each faculty can contribute very much towards these goals through their own classroom and other interactions. Potentially, we can help students achieve their academic and life goals, help our institution to attract, retain and graduate competent graduates, and help provide workforce able to thrive in the very diverse technical environment of today.

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