AC 2011-2545: MASTER APPRENTICE: IS THIS A WORKING MODEL FOR ENGINEERING SCHOOLS?

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Master Apprentice: Is this a working model for engineering schools?
An in-depth look at the current engineering education

This paper starts with a review of historical perspective for engineering education. Why were the engineering schools modeled as advanced master apprentice environments? The paper then briefly looks at the relevant concepts of master apprentice approaches and provides a contrast of that model and the current practices (such as the mentoring practices that are followed in some schools). The current issues and challenges of engineering education are examined. The paper reviews some of the undergraduate issues such as students' approaches to learning, perspectives of engineering classes, and understanding of engineering education. The assumed master apprentice model is identified, examined, and discussed. The validity of the original is discussed for continued engineering education. Guidelines, possibilities and approaches are proposed for institutions to follow to make the engineering school true pedagogical environments that are needed to mentor, train, and educate the students on the next century.

Introduction

Historically US universities were based on bringing a master and teach a large group of apprentices to learn the tools, skills, and the problems solving. This model is more or less continued from late 19th century Europe US universities especially the engineering colleges have tried to produce a number of capable students who can fit in the industrial engine that will take the country to the modern times of technological leadership.

The model has been taken from the general master apprentice model that has been utilize in very similar ways in technical team in civil, mechanical, carpentry, and other artesian shops. This is a working model and has been effectively used in monasteries and religious school. With that industrial development we needed to produce much more number of capable people so there was a need to needed to expand the model. Schools would hire a capable engineer or physicist and ask them to teach a class of students to develop certain masteries. The early engineering schools for that reason looked more like what we call vocational schools the goal was to get the students to a level that they could reproduce what is needed on their own.

This issue is identified by practicing/professional engineers in the industry and corroborated by the professional organizations and engineering educators. All of the companies have to retrain the graduating students. Some industries as well as engineering authorities such as NAE, and scholars in engineering education do demand less mathematical preparation and analysis emphasis in our curriculum, and would like to see more synthesis and creative approaches. There is a need to review what scholars and professionals

By reviewing what is needed and what is said about the problem one can narrow down the problems to the gap, that is, the specific problems (institutional, practical, pedagogic, etc.) that engineering education administrators, educators, and students encounter during the programs of study in engineering. The goal of this paper is examining how we got here, what was the intention of the models that have been adapted for US education systems, and basically how we got here.

Master apprentice

A master is one who has experience and the right skill to create in any area. In the modern day the word master has been changing and replace in higher education by the word “expert”. There are numerous references to masters such as, a master carpenter, a master mechanic, an archer.

An apprentice is a person who learns an skill by working for and under a master. An apprentice usually works for a period of time until the master would be satisfied with the learning or skills.

In today’s engineering school we still carry these ideas. For example the professional licensure for engineers requires not only passing a test, but also working under a certified professional engineer before one can be a professional engineer. Another example can be the MIT experience with electrical engineering. The department was created about 1900. The goal was to develop engineers who are capable to develop the electrical needs for industrial, urban, as well as rural needs. This is the time that the dynamo and creating and harnessing electrical power was at the infancy. The classes would bring bright student who would learn the trade, tools, and ideas from distinguished established engineering icons.

The apprentices would then go to the society to contribute to the industrialization and modernization. The apprentice would be hired based on what they could do which was certified by the name of the school as well as the professors that they would work for. Interestingly, the above two items are still of great importance in the academia.

Examine the premise of this method for university settings: While the method is still followed the main goal of the engineering schools are been shifting and broadening in the last half of a century. Schools are not really hiring masters of trades, but hiring experts whose expertise doe not necessarily reflect their capabilities in practical engineering. The masters at the universities are becoming more and more, faculty with the right mathematical, scientific, and needed capabilities that do not include the mastery of the practical engineering needs as before.

Consequently, the model seems to be working more effectively at the graduate level. However, the undergraduate, where students need more practical and hands on tools of the trade does not seem to be as effective as it used to be in early to the middle 20th century

Engineering in US universities

Engineers in university systems who were in touch with newest development and are master of what they do in each field were to help the farmers and interested people in each state by infusing technical information and practical and state of the art technology and know-how to people, companies, new businesses etc.

In addition to the extension activities, institutions to disseminate advances in mechanics and the effects of machines on society and the natural world were developed. These mechanics institutes sought to not only inform the general public but to significantly influence technical education based upon scientific and philosophical principles.

In the early 1800's, George Birkbeck, a physician and professor of natural philosophy, drove the development of mechanics institutes in London and Glasgow. Mechanics institutes then spread from England and Scotland, to the eastern seaboard of the United States, to Cincinnati.

By 830, there were mechanics institutes in New York City, Philadelphia, Baltimore, Boston and Cincinnati. The catalyst in Cincinnati was John D. Craig who challenged Cincinnati leaders to "form an institution for the invaluable purpose of diffusing the light of science over every department of the useful arts and manufactures: for letting our ingenious artisans and mechanics see that the practice of their respective arts is capable of being derived from scientific principles; and from the great and immutable laws of nature."

From the founding of the institutes to the time of the Civil War, the vision of educating artisans and mechanics in technical, scientific and liberal studies served the communities well. As technology advanced and society's needs evolved, topics beyond mechanics and architecture were added.

World War II experience

During the development of communications and weapon systems the most important questions that engineers had was why they are not the leaders of the developments. The radio frequency research and developments for the radar, and communication as well as the weapon developments that lead to the harnessing of the atomic power was all lead by physicist with the help of engineers. However, the leadership was not by the engineers. Engineers lead the development and implementation because that was their training and their mastery. Upon examination of this effect engineering schools starting with MIT and other national leaders decided that what the engineering curriculums lack is more science and mathematical education. Starting 1950-1960 the engineering programs infused mathematics in to the curriculum; however most of them were still lead and taught by practical capable and master engineers. During these years many schools had engineering faculty also help teach mathematical classes so the information is more palatable to the engineering students .They had a much better connection to application and team work with different departments.

Engineering and undergraduate education changed significantly after WW II due in large measure to federal funding to support research. With the increased emphasis on research, college faculty were hired who could contribute to this research focus and the number of faculty with significant industry experience declined. Curriculums began to change to emphasize mathematics and theory and deemphasize machining and surveying.

One particularly significant change was the emphasis on engineering science that was implemented in the late 1950s. The American Society for Engineering Education had released the findings of a study referred to as the "Gartner Report" which provided a framework for the advancement of engineering science. The report also suggested that the country needed two types of engineering programs: one that was a continuation of the practice oriented programs of the past with upgrades in math, science and liberal arts; the second focused on engineering science to prepare graduates for careers in research labs and academia.

The development of 1970s

The success of the space project was immense. Space project allowed huge amount of money to be devoted to schools and university programs. Engineering programs had a good share of them and what 60s 50s and 60s showed was the practicality and capability of engineers. The mercury and Apollo programs had engineering managers (the original mercury astronauts all had engineering education as well as some military training and flight experience.

1970s is the era that large government money such as NSF and others were granted and universities demanded a different approach from engineering professors. By the middle 70s some engineering departments become leading researchers in practical as well as mathematical and scientific endeavors. During this decade there is a shift from practical experimental work in engineering schools to more mathematical and conceptual work. This effort is aiming at attracting faculty and individuals who can bring more larger research grants to the departments and schools.

Some current consideration

The general trend for colleges of engineering continues to be toward producing graduates with increased math, science and analytical skills. Curricula continue to change away from practical skills to theoretical knowledge.

A number of colleges continue to embrace the cooperative education model however which provides for industry experience in conjunction with theoretical learning. Students in these schools can have 5 – 6 work assignments and will often work at a company over a period of 3 years. Cooperative education employers who embrace this model often provide a master – apprentice framework for these students, pairing the student with a mentor who will facilitate professional growth during this period.

There is a movement away from this model though, even among colleges that include cooperative education. More and more students are moving between employers and not spending as much time at one organization. Many colleges have also instituted undergraduate research and even research cooperative work assignments such that even among cooperative education colleges, more students are shepherded toward research-based careers than industry-based.

What is the mastery the university professor really has? The most important mastery that all professors should have is really the mastery of learning. In addition research professor do have mastery in their field of specialties. In most of these cases the mastery is aimed at research depth and not the practical application and implementation. However in our engineering classes we are not teaching the mastery of learning (which is what professor really should do). Most classes are teaching the facts, manipulations, and derivations that in needed and is considered to be essential to be "good engineers". In most of these the connection with the actual technological development, implementation and design synthesis is not clear. Our classes are full of analysis, mathematics, and high level concepts and less of synthesis and hands-on manipulation.

There has been much written in the past 20 years on the deficiencies in the engineering curriculum. The criticisms are generally not a lack of technical skills but professional skills that are seen as critical for a competitive, global economy. Employers often cite lack of skills in teamwork, communication, innovation, and critical thinking among engineering graduates. Partially in response to this, ABET reformulated accreditation criteria to address the need for programs to develop such skills among students. These new criteria include a need for lifelong learning and to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

There have been some reported gains in these skills but it is clear that much yet needs to be done. Faculty continue to be hired to perform research and to mentor students into research-based fields. Faculty are not hired because they are expert in teamwork, communication, or contemporary issues. Academia's ability to influence students in these arenas is insufficient. The reward systems in place at most universities actually discourages faculty from anything other than a focus on research excellence.

The Final remarks

As educators, our main objective is to create life long learners with the write basis and understanding in engineering and related fields. We need to create technological shape shifters who would adapt to the available as well as future developed technologies. We need to develop creative engineers who help advance technology in their field. What should the engineering schools focus on? We should have more focus on basics, hands on application, synthesis of ideas and design and creative work. We should inspire students to want to learn and be able to systematically learn to develop what they would like to do.

What are the problems of the master/apprentice model as of today? The mastery that the instructors need to focus is mastery of learning. While necessary, providing the information that students should know, is not sufficient for the development of future engineers and problem solvers. We need to help students become thinkers, examiners, learners, and empower them to face new problems and ask better questions. The mastery that we need to provide for the students is to help students ask better questions, relate to development of technology, be tooled with the enough information to learn what they need and adopt to challenging conditions We should demonstrate systematic thinking, analysis, and implementation that lead to better synthesis capabilities.

How can we help the educators to develop better processes and habits to become more effective? Some of this has been addressed with the newly developed program across the nation, and some of the new engineering programs that are based on hands-on discovery. However, the main focus of the educators need be helping students to become self-learners. Students needs to question more, experience more, and not be chained down with too much facts out of context. Almost all of the items that engineering programs are teaching are changing in the next decade except the very basics that are shared with all sciences and engineering. We as educators cannot keep adding more classes, and pack more material in the classes. Teaching facts out of context will only bring about a dogmatic approach to engineering. As educators whose expertise is not the practice of engineering, we should be aware of this fact. We should teach students to critically examine their education, learning process, and goals. Help them be lifelong learners, and help them find their way of learning. For the hands on and the actual engineering, schools have to work very creatively with practicing engineers, and creative faculties and professional in sciences and engineering to bring about applications that inspire students to go through the hard work of learning, examining, and creating problems, solutions, and applications that would make an impact in their lives.

Conclusions

In this paper we introduced a discussion questioning the validity of the master/apprentice model that is used as the basis of the almost all of the US university education systems. This paper introduced the concepts looks at some of the major historical developments in the process and examines the consequences of this model. We also introduced ideas of the goals for education and what can be done to improve the process, and help educators be more efficient.

This paper reviewed of historical perspective for engineering education. Why were the engineering schools modeled as advanced master apprentice environments? Relevant concepts of master apprentice were introduced and contrast of that model and the current practices were discussed. The paper discussed some of the undergraduate issues such as students' approaches to learning, perspectives of engineering classes, and understanding of engineering education. The assumed master apprentice model is identified, examined, and discussed. The validity of the original is discussed for continued engineering education. Guidelines, possibilities and approaches are proposed for institutions to follow to make the engineering school true pedagogical environments that are needed to mentor, train, and educate the students on the next century.

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