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VAN GOGH, GAUGUIN, FLUIDITY AND THE UNDERGRADUATE ENGINEERING EDUCATION

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ABSTRACT

There seems to be a significant difference or gap between the preparedness of graduating engineering students and the value of their skills to North American industry. This fact started to surface in about mid eighties in US as a result of a survey done at that time and also later by the National Society of Professional Engineers in the United States. This paper presents some thoughts as to why such a large gap has appeared during the past decade or so, and what needs to be done to reduce it. A digital curriculum concept will be discussed, as well as student-based teaching and learning. The requirements for change appear to be challenging, as they may include the need for additional space and teaching equipment, thus increasing project and laboratory costs. Recent applications of the various attempts in various campuses in USA and at a Canadian campus are explained.

1. INTRODUCTION

The engineering professions, and also engineering education, have been changing rapidly. At present, few theories exist on how the changes to the profession should be handled in terms of modifying the undergraduate curriculum. The objective of this paper and of this presentation is to share with you some of the information I have gathered and questions I have considered during my recent work at UBC and UBCO.

Changes in engineering education are not new; they have occurred before in North America. The name of a small Soviet satellite, Sputnik, is usually associated with the beginning of these changes. Sputnik is credited with bringing about changes to the engineering curriculum in the late 1950s and early 1960s. A large number of courses in mathematics, science and advanced engineering were added to the undergraduate engineering curricula of that time. Aerospace departments became very popular as well. Many of the professors now teaching engineering in North America were educated with and inherited that curriculum.

However, if we stop to think about it, other "machines" have also changed the world in the past, and with it, engineering. The internal combustion engine, the camera, and the computer have brought about extensive changes in our lives and also in the field of engineering. Each of these machines has changed our expectations and also the quality of life on earth.

We will briefly look at several short examples concerning these machines, followed by some ideas on education, some of which were influenced by a display on fluidity at the University of Michigan in 2002.

2. THE INTERNAL COMBUSTION ENGINE

The internal combustion engine has changed the nature of farming, transportation, cities and suburbs, and has brought about new industries such as tourism, along with the drive-in concept. It is reported that about forty per cent of the U.S. economy now depends on the automobile. If we examine the effect of the internal combustion engine on only farming and the farmer, we can say that as tractors came into use in North America, horse-based agriculture was replaced by tractor-based agriculture. Farmers now require less knowledge about horses but more about machines, fuel, selection of materials for their repairs, lubrication, and so forth. Motorized agriculture has not only changed the nature of farming, but also the farmer in terms of the skills and education he requires. He can now irrigate his fields using a pump powered by a tractor, and repair his equipment in an emergency. Forward-thinking farmers have adopted the new machines; others have resisted change. However, the result of motorized farming may be seen both in the fact of larger farms today as well as in the increased efficiency of their production.

3. THE CAMERA

Still cameras and movie cameras have changed the concept of painting and also the style of presentation of course material in the classroom. We have learned to freeze time and to explain and lecture in a visual way. As for painting, the invention of the camera has changed it completely. Gauguin wrote to Van Gogh in 1886, in loose translation, “The camera has been invented and will be in color soon. We do not have to copy nature; we should paint from our imagination, our dreams, our perception.” These men had the vision and the energy to change their style of painting, and their paintings now hold very respectable places in world museums. The camera changed the concept of painting, the artist, and art as we now know it. Painters such as Van Gogh, Gauguin and Matisse did not imitate their old masters. Instead, they developed a new wave in painting, which required a tremendous amount of courage and determination.

4. THE COMPUTER

Computers have also changed our lives greatly. The way in which I am able to type this paper is an excellent example of how both the way we type and I have changed during the past ten years. Computers have resulted in new hardware and software industries and products that depend on computers, such as the Internet. We depend extensively on the Internet for communication, and the access to and collection of data. I believe that engineering, and undergraduate engineering education in particular, have also changed drastically as a result of the computer.

My concern now is mainly of the impact of the computer on engineering practice and on undergraduate engineering education. We need to quantify this change in the engineering profession, so that the impact of the computer on it can be measured and evaluated. But before we consider that, I would like to share with you a proverb I learned some time ago, which says that “to progress we need to change, to change we have to first change our minds.”

During my study leave at the University of Michigan I observed that the mechanical engineering department in that university had done just that. The university had built a new North Campus and had included in every building the infrastructure necessary for the effective use of computers in education, of which the Computer Assisted Engineering Network (CAEN) is an example. Around the same time, the mechanical engineering department contacted the employers of its graduates, after which it reviewed its curriculum and revised it in a measurable way to include new technology. Later, the department published the results of its findings and the subsequent changes that it made.

To have a better understanding of the changes brought about by the computer, we need to know how computers affect human activities. I think that what my friend David Malaher once said in one of our discussions about computers might be a good representation. He said that “computers are like microscopes; they give us new dimensions.”

We can try to determine what those additional dimensions are. We know that engineers of my generation specialized in one area, working as a “bridge engineer” or “marine engineer,” and that they remained in one area for a long time. Design methodologies and codes did not change a lot. Not any more. Engineers are now expected to be more flexible, to be team players, and to be more creative and synthesis oriented. They are also expected to have more skills. Knowing specific design procedures and the codes is no longer sufficient, as both can easily be programmed or computerized. It is not enough to know how to select a pump and do the pipe head loss calculations as an engineer, as this type of selection and calculations are relatively easily available in a small computer package.

The equations used in engineering and engineering methodology have, however, not changed much over time. We still use force equals mass times acceleration, or Newtonian mechanics. Even the large systems of equations which we now use easily, were known earlier. Companies such as Messerschmidt, the German airplane manufacturer, was said to have had, in the 1930s, six women whose job it was to invert a 6 by 6 matrix for the design of airplane wing profiles, a task which required a day to complete. Similar positions for “matrix inverters” appear to still exist at some European universities; the current version of the job, however, seems to be to input and handle matrices properly in computers. We can thus observe that engineering tools have changed greatly over the past two decades. Some educators claim that “engineering science is dead,” but this remains to be seen. New engineering products still need to be developed, such as renewable energy machines, and for these we need engineering science for modeling, research development and production.

Digital drawing equipment, including rendering for three-dimensional presentation, and “quick prototyping” are new engineering tools. Hand drafting is not only rare today; it is also not considered “professional” by today’s standards. We are now able to do numerical rather than analytical designs, and to collect digital rather than analog signals.

Changes in engineering education are also visible. Books now contain at least a CD with problem-solving software, numerical programs for engineering applications, and various animations, and they refer the reader to a web site for additional information as well. Electronic versions of books are also available. While students still prefer paper books, they are able to follow web-based lectures with color graphics and animations using their laptops in class. Professors are able to communicate with students efficiently using e-mail and course web sites.

Classrooms have also changed; they now have computers and digital projectors, and chalk-based blackboard presentations are rare. Students seem to be more motivated seeing animations of calculations, such as the output from CFD software, visual examples that one can create using a special program. As a result, professors are now able to achieve a higher level of communication using wireless networks available on campus than was previously possible, and to try student-based teaching using case studies and project-based curricula.

While we take books for granted information in general and books in particular were not always easily available. Religious works were the first books to be printed and, prior to that, most books were hand-copied by scribes. In the library of the old Roman city Pergamum (Bergama in Turkey), it is reported that about 5000 scribes copied books for various libraries around the world during the time of the Roman Empire.

In the past, in order to acquire new knowledge, students had to travel long distances. For example, Pythagoras traveled to Babylon (Baghdad) to learn how to calculate the square root of integers, and to learn “his” theorem. Most of us learned this theorem from books; we did not have to go to Baghdad. And today of course, it is possible to obtain even more extensive information using the Internet. With the availability of the Internet and e-mail, we can quickly access any information we need. A relatively new use of the Internet for delivering information that of distance education is already beginning to change the concept of the university. Is it possible that e-books and e-colleges will one day be the norm?

5. THE GAP IN ENGINEERING EDUCATION

Most of the above observations can be seen as tangible results of the development of the computer. The results obtained by the National Society of Professional Engineers in the United States, as shown in figure 1, add a measurable result to these observations. This chart might be a good starting point for thinking about the changes which have occurred in engineering and the corresponding modifications that will have to be made in the undergraduate engineering curriculum. Except in the areas of mathematics and science, there is a definite shortfall in the readiness of new engineers. Teamwork, leadership, and integrative thinking are not the major teaching targets in current North American undergraduate education.

6. ASSUMPTIONS AND POSSIBLE SOLUTIONS

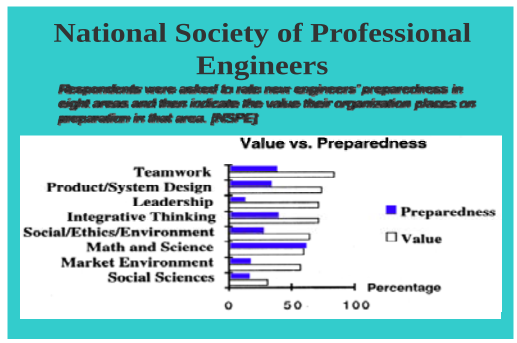

Figure 1 Value vs Preparedness for new engineering graduates

My assumption is that this measurable gap between value and preparedness, as seen in figure 1, is the result of the changing expectations and practices in the engineering workplace, brought about primarily by the use of the computer. In addition, teamwork, leadership and integrative thinking are new dimensions to engineering, and appear to be important to industry. The gap between value and preparedness is similar to the gap experienced by farmers before and after the advent of the internal combustion engine, and by painters after the invention of the camera. In the field of engineering, computers have taken the load of analysis and hand calculation off the engineers, but at the same time have brought new requirements to the profession. Farvardin N gives the following figure in Ulsoy (2007) as a comparison of the expectations from a modern versus classical engineer. This he does without referring to the root of the changes. One can speculate that engineering skills brought by computers such as CAD, FEM took space from the curriculum that was available for soft subjects such as English, psychology etc. We can conjecture that computers allows more detailed design resulting with optimization and requiring team work possibly international in definition.

Traditional Engineer	Modern Engineer
• Problem solver	• Problem finder and solver
• Excellent mastery of technical skills	• Combines technical skills with soft skills
• Understands technical context of work	• Understands the market too
• Is content doing all her/his work in one country	• Thrives on international relations and business opportunities
• Reports up the management chain to MBA	• Hires MBAs

Figure 2 Traditional versus Modern Engineer from Ulsoy 2007

One possible solution for the removal of the gap could be obtained by identifying the role of the computer in the engineering work environment and by building new curricula around this observation. The likely result of such an exercise will be the realization that undergraduate engineering education in the future will have to take place in an environment similar to that of a practicing engineer. That is to say, the type of computer support which the practicing engineer has in his workplace must also be available to the undergraduate engineering student. This has already been accomplished to some degree, as mentioned earlier, at various campuses and possibly first at the University of Michigan.

There seem to exist mainly two basic educational methods. One is the student-centered approach, where the student is evaluated on what he has learned and not on what he does not know; and the teacher-centered approach, where the student is evaluated with quizzes and final examinations to establish the limits of his knowledge, or what he does not know.

Some educators find that teacher-centered instruction assigns a passive role to students. These educators would much rather see that a student's evaluation determine "whether a person can think in a disciplined way." They also add that a student's abilities cannot be measured by the type of short-answer questions commonly used in quizzes and examinations.

While most educators may agree that student-centered teaching is more suitable for teaching creative work, including engineering, the main difficulty seems to be administrative. This seems to be related to the fact that the evaluation of the student's knowledge is still, in general, based on standardized tests such as the Graduate Record Examination (GRE). Standardized examinations are still the basis for acceptance of engineering students into graduate studies and into professional engineering status. This seems to form the basis of accountability of the educational procedure as far as the administration is concerned.

Other educators claim that teacher-based instruction equalizes the educational process by providing exposure to the same material to all students, and to a more organized education through an agreed-upon curriculum. In addition, teacher-centered instruction seems to be preferred by administrative organizations, as already mentioned, for the additional reasons that it is "cheaper" and more accountable, and requires fewer infrastructures such as classroom and laboratory space, educational and laboratory materials, and teacher time for projects. Student-centered education may also be at odds with the current emphasis on "accountability," which tends to focus on the educator's role and responsibility for students' learning, rather than on the role of the student. The main point of discussion for engineering education is, of course, what the engineering curriculum should contain in order to enable students to learn leadership, creative thinking and synthesis.

There are obviously other changes that need to be made in order to simulate an engineer's workplace on campus. These include providing an environment conducive to teamwork, integrative thinking and leadership training (or TIL in short). The objectives to be met are similar to those found in the teaching of team sports, and require continuous preparation and coaching, plus competitions.

Some of the results I observed at the University of Michigan were most impressive. With the availability of CFD code in CAEN, referred to above, a University of Michigan fourth year student was able to calculate the three-dimensional flow around the keel of a sailboat. This was for a term paper worth twenty per cent of the course mark in an undergraduate course on sailboat design. At UBC similar attempts have been made to increase the exposure of students to various new engineering design tools in various courses. In fluid mechanics we have begun to include some of the concepts of CFD in undergraduate courses, and recently, CFD laboratory content was included in the third year fluid mechanics course, using FLOWLAB software. However, we still insist on teaching many concepts requiring extensive analysis, such as boundary layer flow, in a lecture-based format. One can question whether there are more effective ways to introduce such concepts, such as with the help of computers physical experiments. Do we really need extensive analysis such as perturbation methods at this level in order to introduce mainly concepts? To answer this question, we need to know if the engineer of the future will need to use an extensive amount of analysis or will be using a computer-based approach such as a CFD code for design. We can ask if he will be using software provided by salespeople to select fans, blowers, pumps, etc., for his design.

We need to estimate what type of concepts an engineer will need and what type of educational tools we must use to teach such concepts in the most educationally efficient way. Among other things, we need to know if we require extensive, in-class analysis in order to teach basic concepts or if we can use new digital tools. A very good and effective approach now with the computers is the usage of simulation for the instruction engine operations or navigational problems. The student is expected to think and solve problems associated with ship operation but the problem is visible and realistic. The procedure also offers a student based learning procedure and valuation.

In my opinion, a student-centered approach is more appropriate, especially for TIL, but an integrated approach with proper checks and balances is also required for professional studies. A recipe for change does not seem to exist, and there may be a number of solutions for a new digital curriculum and the associated environment for the teaching of TIL. In short, we need to answer the following questions:

How can we respond to the existing value versus preparedness-gap in engineering education?
How can we effectively use digital (computer-based) general engineering and design tools in education?

My suggestions may be summarized as follows. First, we need to bring student-based teaching and modern engineering practice into the classroom and, second, we need to modify engineering education to stress teamwork, design, creativity and synthesis (rather than analysis at this level), possibly leaving analysis to computers. This will require that we bring numerical analysis tools into undergraduate education.

This will not be an easy task and we will need "fluidity" or change. In order to change our educational methods, we must first change our minds. This refers to the fact that change is made by individuals first and then by the institutions and is a highly personal and long experience. This required change of mind may possibly be the most difficult task for educators. We must also decide not to compete with the computer, and we should stop imitating our own old masters, that is, our professors, much as Van Gogh, Gauguin and Matisse stopped painting like their masters. Instead, we should give new digital tools to our students so that they can design the machines they can imagine or dream about. We need to accept the fact that part of the reason for the existence of this gap is that industry is way ahead of universities and colleges in the development and use of computer-aided engineering and design. New engineering tools have not been developed at universities; they are not products of universities; and we really do not know how to use them properly in universities. An additional problem is that even if we have these products, we do not know how to use them effectively for the education of future engineers. In addition, we may not have sufficient space and the necessary infrastructure for teaching a digital curriculum.

All of the above will require that we increase the numerical and digital components of our courses. I recommend integrating computers into our engineering courses and curriculum. In this way the classical, analysis-based component of undergraduate courses could be reduced significantly, and engineering concepts could then be explained through numerical results rather than by extensive analysis.

Computers also offer the opportunity for student-based teaching, thus enhancing teamwork. Engineering case study packages, such as those developed for NSF under the LITEE program, offer the opportunity to introduce students to TIL. I have observed that students do an excellent job of learning when computer-based tools are freely available to them as part of the curriculum.

7. THE CHANGE REPORTED SO FAR

We all observed that most universities are connected to internet in a wired or wireless way. They extended the computer capacities but not necessarily for education and without an integrated approach. In USA national Science Foundation spent substantial amount of money to restructure engineering education. New concepts in teaching were encouraged to increase the quality of engineering education.

Michael Bernitsas 2002 reported that in the Naval Architecture curriculum at the University of Michigan the following subjects and educational procedures were added to the curriculum.

The new curriculum (1994) has courses in manufacturing, life cycle cost, industrial design course (second year) before 3rd year core courses.
Team work communication skills ethics, environmental awareness, included in (1997-2000)
Simulation based environments to test virtual prototypes (Computer aided design)

These all seem to be in the direction to close the gap discussed above.

An MIT initiative that could revolutionize learning started in September 2003.

The Massachusetts Institute of Technology (MIT), which decided in 2001 to put all its courses on the Internet, in September 2003 moved its Open Course Ware (OCW). Electronically downloadable books and course ware is now available to all students around the world. This initiative may not reduce the gap but is surely digitising the undergraduate education and opening new frontiers opportunities to educators.

Latorre (1997) reported the modifications made to the Naval Architecture program at the University of New Orleans. He lists similar short comings and lists modifications made to the curriculum to remove the deficiencies. He also provides a project based future view of the naval architecture program at UNO.
At the University of British Columbia BC Canada (UBCO) a new engineering school started in 2005. With that a completely revised curriculum was designed in 2004. Some of the fist year first term courses are listed below.

Statics APSC 180 (3)	3-0-2
Engineering Analysis I APSC (3)	3-0-1
Engineering computation and Instrumentation APSC (3)	2-2-0
Social Electives (3)	3-0-0
Engineering Fundamentals (3) APSC170	2-0-2 *
Matter and Energy (3) 3-0-1 APSC	4-2-2
(18) Credits 17-4-5 contacts	

Two of the features for this set of courses is rather unique in engineering education and its application was very successful. One of them is the inclusion of a full course on Statics during this term. The second more radical is the development of the Engineering fundamentals course that included emphasis on team development, design, project based learning, budgeting etc. The student groups designed, built and competed with their designs. The judges for the competition were the invited professional engineers of the community not the instructors. The students learned the benefits and the difficulties of team work and designed, planned, built a working device to perform a well defined task. This was a difficult course to teach but very valuable to students as the skills learned during this course were used in most of the later project based courses Labun (2009). During the development of this new engineering program it was agreed upon that all courses and labs would be designed assuming that the students have a laptop computer.

In addition a second year design course used a project based on an air cushion vehicle. Students tested the pressure field under the cushion, optimized the weight of the structure, measured the electrical energy consumed by programming a board. A weighted formula was used to evaluate the transportation performance based on the weight carried along a basketball court and the energy consumes. We believed that these two courses helped the student develop team work, communication design, integration skills.

Figure 2 One of the first year design projects for APSC 170 at UBCO

Figure 3 UBCO second year Air cushion design competition equally stressing team work, communication.

Similar course developments at the mechanical engineering department at UBC resulted with an award winning program called Mech 2 for the second year Ostaficuk et al (2008). This is a worth studying program as it offers a very creative a project based environment to the students. Various very effective and valuable course designs are underway. They still remain at individual course or project level and a more comprehensive look at the general engineering undergraduate education is required and forthcoming. We see rather interesting educational changes and developments in Physics and Medical schools now.
Bronsart R. Clauss G (2006) reported a very interesting inter university usage of computer aided education in engineering.

8. CONCLUSION

I believe that in order to progress we need to change, and in order to change, we must first change our minds. We need to integrate the use of computers into our courses for teaching engineering and TIL. For this we need a digital curriculum that includes the computer as a teaching and an engineering design tool. When we have reviewed all the courses in our curriculum and made the required changes to them, the result will be a modern, successful engineering program that is more relevant to the requirements of industry, and the preparedness gap between engineering education and industry will have been removed. As change is a continuous process we should be prepared for the long term and continuous nature of the energy required for such a change.

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