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Education and Training in the Field of Machines and Mechanisms (A Comparative Study)

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Abstract. Machines and mechanisms have always been used as tools to improve both the lives and lifestyles of mankind. Human beings started using them by converting natural resources into various forms and shapes of ancient man-made tools. Similar has been the case with one of the most basic areas of mechanical engineering: machines and mechanisms, a field in which human species' invention of the wheel emerged as the foremost and basic entity. As the engineering world progresses the upcoming engineers have to be educated and trained for these latest technological developments and also have to be imparted with more skills in the form of research and development (R&D) capability. This paper gives an overview of the educational status and training facilities in the field of 'machines and mechanism' in a developing country like Saudi Arabia. The study has revealed that the Kingdom is presently focusing on such areas as mechanics, kinematics, machine design, machine dynamics and theory of machines which are mostly taught in the universities across the Kingdom. The educational and training status of universities in Saudi Arabia compared with those of educationally developed countries like USA in the field of 'machines and mechanism' is discussed. The study revealed that the nature of laboratory based training work, the coverage of the related areas and the methods of teaching these highly technical courses in Saudi universities need to be further improved in order to become comparable to their counterparts in the world. Recently, the Kingdom has initiated work in the field of 'nano technology'. What would be its impact on the design and development of future curricula pertaining to machines and mechanisms is highlighted. The paper concludes with certain recommendations that can help policy planners in the field of engineering education, in general, and machines and mechanisms, in particular for the successful future of developing nations to keep pace with the latest innovations.

Keywords: mechanical engineering, university education, curricula, machines, mechanisms, technologies.

1. Introduction

Right from the very beginning, the human race has tried innovations to make things under its control and to make life easier for the upcoming generations. Starting from those ancient days of human civilization, discoverers and inventors constantly looked forward, whether it is the design of a simple toy car or a complex aircraft and spaceship system. In such a scenario, the role of academicians in the context of education, research and training has always been most critical and tedious. It started from the ancient period by the invention of wheel and it has reached the latest flying cars made by a students' group of the Massachusetts Institute of Technology (MIT) named "*Terrafugia*". Thus, our human civilization always remains dependent on engineers and various engineering gadgets for the fulfillment of its needs in every instant of its life. Development of machines, be it the lathe of the industrial revolution or the present day nano-machines, all have been very important in the overall development of humans. Ray Kurzweil, one of 18 thinkers chosen by the US National Academy of Engineering to identify the great technological challenges facing humanity in the 21st century, is quoted saying that "Humanity is on the brink of advances that will see tiny robots implanted in people's brains to make them more intelligent" [1].

The engineer believes that machines and humans will eventually merge through devices implanted in the body to boost intelligence and health. So, in the near future we'll have intelligent nanobots go into our brains to make us smarter. It has already been reported that efforts are being made to develop anthropomorphic robot hands, an endeavor to imitate physiologically the human-hand to be employed in future robots [2- 4]. Such versatile and ubiquitous is the world of machines and therefore mechanisms which make a machine work in the requisite framework. But for all of these technological advancements, the pre-requisite is the higher education, which actually leads us to the path of progress in this complex scientific world. In the purview of the present paper, it is important to know the role of machines and mechanisms in education and thus the development of human civilization, especially in developing countries like Saudi Arabia.

It is important to note that almost all selected universities in the USA, Canada and Saudi Arabia have high international ranking. This makes the comparison more meaningful. The status of education and training in the selected universities can then be assessed by comparing the offering of courses to get a *general overview* of the situation in these countries. Of course, a deeper study can be undertaken to include many other aspects and factors such as credit hours, teacher/student ratio, level of equipment volume in laboratories, level of strength of the faculty, *etc*. Since training is done primarily in laboratories, class projects, and senior projects, it is assumed here that all these training activities are undertaken to very high and comparable standards. Of course a deeper investigation might reveal different results. Another important aspect of the comparison, which is not considered in this study, is the output of the educational process at the time of graduation or a few years later. Such factors might also be related to existing opportunities to graduates from these universities. This should lead to a more comprehensive comparative study which goes beyond this general overview.

The next section deals with specifying various aspects of the field of machines and mechanisms, and how it is important for engineering applications.

2. Machines and Mechanisms

Mechanical Engineering is one of the oldest and broadest engineering disciplines. This field of engineering applies the principles of physics and materials science for analysis, design, manufacturing, and maintenance of mechanical systems. It is the branch of engineering that involves the production and usage of heat and mechanical power for the design, production, and operation of *machines* and tools [5]. The different sub areas of mechanical engineering discipline can be statics and dynamics; strength of materials and solid mechanics; instrumentation and measurement; thermodynamics, heat transfer, energy conversion and HVAC (heating, ventilation, and air conditioning); fluid mechanics and fluid dynamics; mechanism design (including kinematics and dynamics); manufacturing technology or processes; hydraulics or pneumatics; engineering design; mechatronics and control theory; material engineering; drafting, CAD (Computer Aided Design), CAM (Computer Aided Manufacturing) and CIM (Computer Integrated Manufacturing); and many more. Of all the branches listed above, one of the most important branches is that of mechanism.

A *mechanism* is a combination of resistant bodies, so interconnected that by applying force or motion to one or more of those bodies, some of those bodies are caused to perform desired work accompanied by desired motions [6]. The connections present in a mechanism are called kinematic pairs. Kinematic pairs can be classified as higher pair or lower pair. Sometimes an entire machine may be referred to as a mechanism. Examples include the steering mechanism in a car, or the winding mechanism of a wristwatch. When one of the links of a kinematic chain is fixed, the chain is known as a mechanism. Mechanisms are used to convert one type of motion into another. Multiple mechanisms are machines.

The role of machines and mechanisms in engineering world has always been of utmost importance ever since the inception of basic machines in the pre-industrial revolution days. Between the 1860s and 1960s there was an extraordinary quantum leap in humanity's capacity to transform raw metal into very sophisticated machines. Together with contemporary developments in chemistry and electrical and electronics technology, this revolution in metalworking formed the industrial backbone of the modern world [7]. Whether it is air travel or satellite based communication, links and mechanisms form an essential part of all the gadgets associated with these technologies. In the present paper, the emphasis is on machines and mechanisms because they are the ubiquitous tools of modern manufacturing and right up to 1980s, they occupied an iconic position in debates about industrial modernization.

In the late nineteenth century, producing pedal-operated sewing machines and bicycles was considered something like a challenge. In the 1940s, things changed so much that the industrialized nations produced high performance aero-engines and combat aircrafts in thousands. All space agencies starting from the American NASA (National Aeronautics and Space Administration) to ISRO (Indian Space Research Organization) have been producing complex mechanisms and linkages for the cryogenic engines, space stations or satellites for that matter. It is evident thus, from this discussion, that machines and mechanisms form the basic part of any engineering process, and it is not restricted only to mechanical engineering applications but in all other engineering fields as well. The next section of the paper discusses education and training in this ever growing universal field of machines and mechanisms in general.

3. Education and Training in the field of Machines & Mechanisms

Importance of education has always been there ever since the humans realized the importance of knowledge in their lives. The overall goal of engineering education is to prepare students to practice engineering and, in particular, to deal with the forces and materials of nature [8]. And so is the case of acquiring higher education to cross the barriers of ignorance and move towards creative innovations. If these innovations are technological in nature, then the importance of higher education can never be ignored, and that too in the world where the curve for the rate of obsolescence is increasingly steep. For a country to achieve big milestones in the newest technologies, it is very important for its institutions to impart high quality higher education to its citizens.

In the engineering context, the higher education is mainly imparted through high quality labs that may contain top-notch latest gadgets, to let the students understand the technologies in a practical manner. The importance of high quality laboratories can be realized more in the case of the lesser industrialized nations like Saudi Arabia. From the earliest days of engineering education, instructional laboratories have been an essential part of undergraduate and, in some cases, graduate programs. As an example, it is interesting to note that the first engineering school in the United States, the U.S. Military Academy, founded at West Point, New York, in 1802 to produce and train military engineers [9], was based in part on the French curricular model of mathematical rigor, and was also coupled with practice, striking a balance of sorts between theory and practice. For laboratory courses, engineering faculty are much more likely to identify course goals than they are to specify student learning objectives.

A common goal is to relate theory and practice or to bring the “real world” into an otherwise theoretical education. Another goal is to provide motivation either to continue in the study of engineering or to follow a particular course of study. The American Accreditation Board for

Engineering and Technology (ABET) also gives enough emphasis to lab work and students' performance in some courses gets enough weight just on the practical part of the course. The laboratory work in the fields of machines and mechanisms is also of utmost importance because of its significance in the mechanical engineering arena. Some of the modern tools of teaching and training in this particular area, and for other engineering areas for that matter, include but are not limited to overhead projectors, laptop computers, and calculators. Newer tools such as "smartphones" and games (both online and offline) are beginning to draw serious attention for their learning potential [10].

Although some of these tools are already in use by teaching institutions all over the world, many of the newer technologies need to be implemented to make sure that students properly receive instructional classes they are attending in traditional type of learning. In developing countries, specifically Saudi Arabia, the engineering institutions are using teaching tools such as Liquid Crystal Display (LCD) projectors with wireless access, net uploads of teaching materials *etc*. and modern lab facilities as well. What more can be done in this respect is to employ tools like class web blogs, clickers and smart phones to share the students' problems and suggestions, discuss assignment questions *etc*.

The next section deals with the global vis-à-vis Saudi Arabian scenarios considering the type of courses being taught, and their practical part, through labs, specifically in the area of machines and mechanisms.

4. The Global Scenario

In general, mechanical engineering is the greenest of all the areas of engineering. Within that, the areas related to machines and mechanisms are numerous. The courses taught in this area of mechanical engineering are mostly the same in almost all the universities throughout the world. In the Western world, courses such as statics and within that statics of deformable solids is common along with a few courses like kinematics and dynamics, and intermediate dynamics of machines, as is taught in US universities like Carnegie Mellon University. Some more courses such as robotics and micro/nano robotics are also included in this category. Almost all major universities of US and Canada are considered here which are listed in the table of comparisons.

This study considers three countries, USA, Canada and Saudi Arabia. The sample of American universities consists of 20 universities primarily from the top 500 universities. The Canadian sample consists of 17 universities which have high international ranking. For example, the University of Saskatchewan's College of Engineering and the Mechanical Engineering programs are ranked in the top 20 schools in North America. The Canadian Engineering Accreditation Board has accredited the Department of Mechanical Engineering since the beginning of the program in 1965 [11]. Since Saudi Arabia has a small number of universities, the KSA sample consists of 7 prominent universities. Remaining universities or colleges are either under construction or have recently been established.

The methodology is to study the courses, taught in each university at the undergraduate level, related to machines and mechanisms as per the topic of the paper. The different topics listed are categorized in similar types of areas as is there in the case of the area "Mechanisms (Analysis and Design)" where in, both, the Analysis and the Design aspects relating to different types of mechanisms are considered. Ten areas are considered to come in the purview of the present paper. Table 1 shows nine areas that appear in US universities as indicated by their websites [11].

Table 1. Universities in US offering courses covering topics of machines and mechanisms.

Courses	Universities in USA
Combustion Engines	1,4,16,17,18,20
Kinematics of Machines/Mechanisms	1,2,5,7,8,11,12,15, 20
Mechanisms (Analysis and Design)	2,10,12,13,14,15,17,18
Dynamics of Machines/Components	1,2,3,4,6,7,8,9,10,11,12, 13,14,15,16,17,18,19,20
Robotics	1,4,8,9,16,20
Manufacturing Processes/Machines	3,4,5,7,11,12,13,14,15,16
Nanomachines	2,4, 20
Static Machines	1,9,12,15
Motors and Turbomachinery	5,17,20

Note: *Universities are given numbers as are listed in Appendix* A.

Similarly, the sample of main universities of Canada is considered and the results are shown in Table 2. In case of Canadian universities, an additional course named "Fluid Machinery" is being included, which is being offered in Carleton University and University of Ottawa. This course covers the types of fluid machinery, including details of machines such as pumps, compressors and turbines. Finally, in developing countries, the KSA model is chosen where the sample of seven universities is evaluated. The results are given in Table 3.

Table 2. Universities in Canada offering courses covering topics of machines and mechanisms.

Courses	Universities in Canada
Combustion Engines	1,2,5,15,17
Kinematics of Machines/Mechanisms	2,7,8,10,12,13,15,17
Mechanisms (Analysis and Design)	1, 3,4,5,6,7,8,9,10, 11,12,14,15,17
Dynamics of Machines/Components	1,2,4,5,6,7,8,9,10,11, 12,13,14,15,16,17
Robotics	1,2,3,5,9,13,14,15
Manufacturing Processes/Machines	4,6,7,8,9,10,13,15
Nanomachines	None
Static Machines	4
Motors and Turbomachinery	2,5,15,17
Fluid Machinery	3,9

Note: *Universities are given as numbers as are listed in Appendix* B.

From the research, it is pretty evident that almost all selected universities cover most of the topics related to machines and mechanisms as shown in Table 4. The results are further shown in Fig. 1 in the form of 3-D chart where in the percentage of institutions offering such courses in each country are considered. Though there are thousands of universities in US alone, primarily the top ones were considered for the study according to ranking of engineering colleges in US universities [12]. Similar is the case with Canada, where too, the teaching standards are at par with the institutions in US.

Table 3. Universities in KSA offering courses covering topics of machines and mechanisms.

Courses	Universities in KSA
Combustion Engines	2,5
Kinematics of Machines/Mechanisms	1
Mechanisms (Analysis and Design)	1,2,3,4,7
Dynamics of Machines/Components	1,2,3,4,5,7
Robotics	2,7
Manufacturing Processes/Machines	1,3,4,5,6,7
Nanomachines	2
Static Machines	2,6,7
Motors and Turbomachinery	2,7

Note: *Universities are given as numbers as are listed in Appendix* C.

Table 4. Percentages of universities in three countries (KSA, USA and Canada) covering topics of machines and mechanisms.

No.	Course Title	Percentage of Universities offering courses in machines and mechanisms		
		USA	CANADA	KSA
1	Combustion Engines	30.00	29.41	28.57
2	Kinematics of Machines/Mechanisms	45.00	47.06	14.29
3	Mechanisms (Analysis and Design)	40.00	82.35	71.43
4	Dynamics of Machines/Components	95.00	94.12	85.71
5	Robotics	30.00	47.06	28.57
6	Manufacturing Processes/Machines	50.00	47.06	85.71
7	Nanomachines	15.00	0.00	14.29
8	Static Machines	20.00	5.88	42.86
9	Motors and Turbomachinery	15.00	23.53	28.57
10	Fluid Machinery	0.00	11.76	0.00

In the case of KSA (Kingdom of Saudi Arabia), it is noted that institutions are very limited here, as there are twenty public universities, in total. Out of these twenty, five or six are well-established with big campuses and a plethora of faculties and courses. The rest are still in the stage of infancy. The government has already sanctioned many more state of the art universities but most of them are still under construction. There are also a number of private universities and colleges which are also recently established.

The combustion engines course everywhere covers the different types of internal combustion engines, developments in direct ignition, rotary, pre-chamber, and stratified charge engines including the design of the combustion chamber. It is indeed an important subject for prospective mechanical engineers, although, unfortunately, not many universities are offering such a course, especially in US and Canada (both 30%), as is evident from Fig. 1. In KSA, about 29% of universities offer such a course approximately, considering the sample of universities selected from each country. The other course which is rarely found is that of "Static Machines" which is covering nuts, bolts and fasteners and the various aspects of their designs.

One thing which is very prominent is the absence of courses on kinematics of machines/mechanisms in the universities of Saudi Arabia. It is present only in one university which is King Abdul Aziz University and is the first university in the Kingdom to have been accredited by ABET recently. Robotics is also an area that is widely covered in the engineering faculties across US and Canada. In some universities in US, *e.g*., Carnegie Mellon University, even Micro and Nano-robotics is covered, though peripherally. In contrast, in KSA, only one university, *i.e.,* King Faisal University has presented a course related to Robotics in its Mechanical Engineering Undergraduate Program.

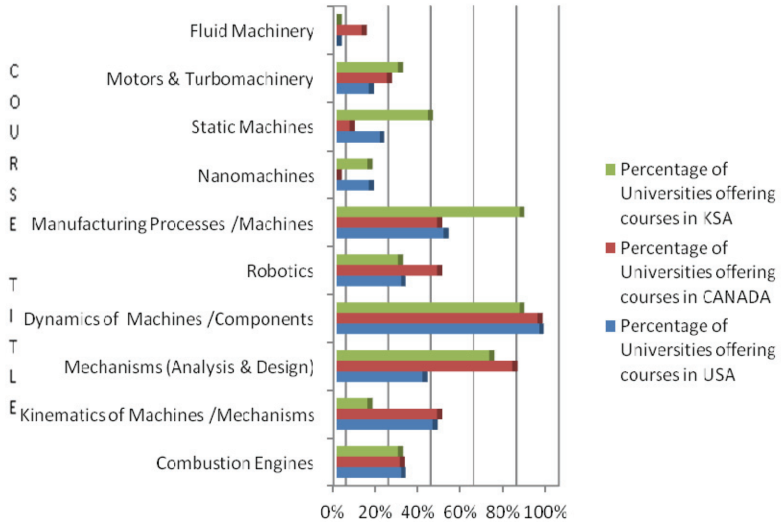

Fig. 1. Percentage of institutions offering mechanical engineering courses.

The progress of educational reforms has been a slow process, which have got very recently a shot in the arm with a large educational budget allocated by the Kingdom to build specialized universities. Barely three or four years back, KSA was having only three main universities having engineering and medicine courses, namely King Fahad University of Petroleum and Minerals (KFUPM), King Abdulaziz University (KAU) and King Saud University (KSU). All the three universities are still providing guidance for the upcoming universities in the Kingdom. The next section describes some emerging trends in the education industry concerning the areas related to machines and mechanisms.

It is to be emphasized that this study focuses on the existence of courses in selected universities rather than on quality or time spent in teaching and training in these courses. However, quality is implicitly included in the choice of these universities where primarily top ranking universities are selected from the USA and Canada while three of the Saudi Universities are ABET accredited and have some ranking among top universities meaning that they are basically at par with their counterparts in the USA and Canada [12].

5. Statistical Analysis

Three classes of statistical hypotheses have been formulated prior to collecting the data for every course and then tested after data collection. The basic framework is that data from Saudi Arabia can be viewed as exhaustive (no sampling) since new universities are basically under construction and almost all of them are built and directed by the major universities included in the study. Thus, USA and Canada samples can be compared to KSA data. Let p_{ij} be the proportion of universities offering course i in country j, where $i = 1, 2, 3, \ldots, 10$ and $j = 0, 1$ or 2 denoting KSA, USA, and CANADA respectively. Then there are 30 formulated hypotheses as follows:

1- First ten hypotheses compare USA with KSA:

$$H_{0i}: p_{i1} \leq p_{i0}, \qquad i = 1, 2, \ldots, 10$$

$$H_{1i}: p_{i1} > p_{i0}, \qquad i = 1, 2, \ldots, 10$$

2- Second ten hypotheses compare Canada with KSA:

$$H_{0i}: p_{i2} \leq p_{i0}, \qquad i = 1, 2, \ldots, 10$$

$$H_{1i}: p_{i2} > p_{i0}, \qquad i = 1, 2, \ldots, 10$$

3- Third ten hypotheses compare USA with Canada:

$$H_{0i}: p_{i1} = p_{i2}, \qquad i = 1, 2, \ldots, 10$$

$$H_{1i}: p_{i1} \neq p_{i2}, \qquad i = 1, 2, \ldots, 10$$

The USA sample, made up of 20 universities, might be viewed as sampling with replacement because the population of universities in the USA is large. Thus, the binomial distribution might be used, and since the sample size is relatively large (≥ 20) the normal distribution can also be used. Here, we use the binomial distribution. On the other hand, the Canadian sample has 17 universities which is less than 20. Thus, the binomial distribution is used with parameters p_{i0} and $(1 - p_{i0})$ under the assumption that the null hypothesis is true. Here, in both cases the true proportion for any course can be assumed equal to p_{i0} for every course i. The level of significance, α, is assumed to be 0.20. However, when we deal with discrete distributions we might need to get a lower value of α, say α_0, and we *reject the null hypothesis when the proportion is too large*. The rejection region is determined as shown in the examples below. For comparisons between the USA and Canada we use Fisher's Exact Test [14, 15], with n_1 = 20 and n_2 = 17 for the USA and Canada, respectively.

In the first case, we use the course title 'static machines', *i.e.* i = 8, to compare USA with KSA using the binomial distribution as follows. Reject the null hypothesis if the sample proportion is too large. The level of significance is α_0 = 0.19136. If the sample proportion corresponds to a cumulative probability lower than this α_0, then reject the null hypothesis; otherwise the null hypothesis is not rejected. Here, the sample proportion is 0.2 = (4/20) which corresponds to cumulative probability of 0.99169 which falls in the acceptance region, hence, the hypothesis cannot be rejected. This means that there is no evidence that supports the assertion that KSA is suffering from a deficiency in this course vis-à-vis USA.

The second example uses course title 'Kinematics of Machines/Mechanisms', i = 2, to compare Canada with KSA using the binomial distribution. Reject the null hypothesis if the sample proportion is too large. The level of significance is α_0 = 0.08360. If the sample proportion corresponds to a cumulative probability lower than this α_0, then reject the null hypothesis; otherwise the null hypothesis is not rejected. Here, the sample proportion is 0.4706 = (8/17) which corresponds to cumulative probability of 0.00126 which falls in the rejection region, hence, the hypothesis is rejected. This means that there is evidence that supports the assertion that KSA is suffering from a deficiency in this course vis-à-vis Canada.

The last example uses the course title 'Mechanisms (Analysis and Design)', i = 3, to compare USA with Canada using Fisher's Exact Test, which uses the hypergeometric distribution, because the sample sizes are relatively small. This example will give the results for three alternative hypotheses; H_{13}: $p_{31} < p_{32}$, H_{13}: $p_{31} > p_{32}$, and H_{13}: $p_{31} \neq p_{32}$. The first two alternative hypotheses, included here just for illustrative purposes, are one-tail tests while the last one, which is our original hypothesis, is a two-tailed test. The corresponding contingency table for this case with p-values is shown in Table 5 below:

Table 5. Contingency table for Fisher's Exact Test of offering the course 'Mechanisms (Analysis and Design) with p-values for three alternative hypotheses.

Offer Status	USA Universities	Canada Universities	Total
Yes, they offer course 3	14	5	19
No, they do not offer course 3	6	12	18
Total	20	17	37

p-values
Left : p-value = 0.997717
Right : p-value = 0.015855
2-Tail : p-value = 0.021709

The implication of the two-tail p-value, in this example, is that if the level of significance is 0.05, then the null hypothesis rejected. As with the first two examples, the decision to reject was made at a higher level of significance of around 20% which is normal for such studies. A summary of results of all these tests is shown in Table 6.

Table 6. Results of the tests of hypotheses for comparing the three countries.

Course No.	USA *vs*. KSA		Canada *vs*. KSA		USA *vs*. Canada	
	α_0	Decision	α_0	Decision	p-value	Decision
1	0.18612	Do not reject	0.18640	Do not reject	1	Do not reject
2	0.14662	Reject	0.08360	Reject	1	Do not reject
3	0.13432	Do not reject	0.09697	Do not reject	0.021709	Reject
4	0.19841	Reject	0.07270	Do not reject	1	Do not reject
5	0.18612	Do not reject	0.08192	Reject	0.327674	Do not reject
6	0.19841	Do not reject	0.07270	Do not reject	1	Do not reject
7	0.14662	Do not reject	0.08360	Do not reject	0.234234	Reject
8	0.19136	Do not reject	0.13923	Do not reject	0.347919	Do not reject
9	0.18612	Do not reject	0.18640	Do not reject	0.679995	Do not reject
10	0.00000	Do not reject	1.00000	Reject	0.204204	Reject

6. Some Emerging Trends

Engineers, especially mechanical engineers, have been involved intimately with the development of machines; with mechanisms that use energy inputs to deliver desirable results. Indeed their preoccupation with machinery and with applying machinery to create wealth for their employers may be an intellectual barrier to the longer term goal of delivering a sustainable society. Future of the human race is standing on the corridors of altogether a different kind of technological development: nanotechnology. The world has already witnessed applications of nanotechnology in areas like manufacturing, automotive industry, aerospace engineering, biomedical engineering, building and construction industry, glass industry, diagnostics, textiles, consumer products, water engineering, drug delivery systems and nano computing.

Fast and extensive progress is being observed in many fields. For example, it has been reported that nanotechnology would have immense effect on the future of automotive industry and manufacturing processes in the Victorian automotive industry in Australia [13] and with the passage of time, these developments are likely to have sustaining improvements in basic properties of future materials in terms of such features as the optical, structural, thermal, magnetic, catalytic electrical and properties of materials. Surprisingly, research is going on in such areas which humans could never have imagined. One of the examples of such kind of researches include inserting nano robots in the brain for making a person intelligent to different types of nano machines which when used in the industry, would revolutionize every bit of evolution. And how do we gain from such nano-robots in the future? That is best answered by a US inventor, involved in nano robots, when he said "We'll have intelligent nanobots go into our brains through the capillaries and interact directly with our biological neurons, which will make us smarter, remember things better and automatically go into full emergent virtual reality environments through the nervous system" [1].

Thus, on the basis of the aforementioned facts, it is evident that together with information technology, biotechnology and cognitive science, nanotechnology is expected to radically alter the human conditions within a short span of time, probably not exceeding two to three decades or so.

7. Conclusions and Recommendations

Imparting education has never been easy, especially when it is in highly technical areas of engineering. This paper's scope is limited to the courses taught only at undergraduate level. However, further research may be undertaken wherein the researchers may include labs as well graduate courses. Though there were differences in contents of the courses taught in various universities in the areas of machines and mechanisms, still most of them are almost the same.

By the topics chosen for evaluation in the aforementioned areas, it was found that most of the universities in the US and Canada have included them in their mechanical engineering programs. As far as the topic Combustion Engines is concerned, it was found that closer to 30% of the universities in US are teaching it, while it is much lesser in Canada (18%). While in KSA, it is almost the same as in US. The authors recommend that the combustion engines topic, being a prime area of mechanical engineering, should be given more importance and should appear more in the curricula of universities of the world, especially in Canada.

Similarly Kinematics of Machines/mechanisms should be covered more in the universities in KSA, where it is rarely found in the list of universities' courses (only 14%). The courses related to Robotics are also not many even in the top notch universities in US (30%), although it has always been, since its inception, an important area for engineers. Moreover, topics pertaining to fluid machinery should be included in the curricula of the universities in US and KSA which is not at all there now (as far as our samples indicate), particularly when it is there in two of the sampled universities in Canada.

It is also because the students are already learning the basic concepts of fluid mechanics, both as a core course and in special fluid mechanics labs, in most of the undergraduate programs. It will be of great help for the students to learn about the mechanical aspects of the fluid machines lab before doing the actual experiments. Similarly, Static Machines is one such course that needs urgent attention of the curricula designers of Canadian universities (only 6%), because they essentially are part of any machine. Finally, Nano-Machines, which is today the hottest topic of engineering, has to find its place in curricula of the universities everywhere, because this is what is going to be the future of engineering per se. Unfortunately it is not available as a course in Canada, and in the US and KSA, it is available only in 15% and 14% of the sampled universities respectively. Emphasis should be given at imparting training in this course, so that at least students should know about the basics of future machines which are expected to replace each and every machine in every part of the world in the future. The nano-machine course is especially recommended for KSA, because the developing countries cannot lag behind the developed ones too much once globalization has opened all the borders for trade and commerce throughout the world.

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Appendix A*

List of Universities in USA

1. University of Alabama, (351=, 32.61; 278, 12.00)
2. University of Arizona, (160, 52.35; 158, 18.00)
3. University of Arkansas, (551-600, 16.89)
4. Carnegie Mellon University, (34, 81.80; 12, 55.00)
5. Eastern Michigan University, (N/A; N/A)
6. University of Iowa, (188, 48.74; 295=, 12.00)
7. University of Minnesota, (96, 66.58; 80, 27.00)
8. University of Mississippi, (N/A; N/A)
9. Massachusetts Institute of Technology (MIT), (5, 98.19; 1, 100.00)
10. University of Oklahoma, (401-450, 27.71)
11. University of Texas, (67, 71.24; 27, 43.00)
12. University of Virginia, (130, 58.30; 262=, 13.00)
13. Washington State University, (351, 32.61; 244=, 14.00)
14. University of Florida, (N/A; N/A)
15. Ohio State University, (125, 59.05; 157, 18.00)
16. Georgia Technical College, (N/A; N/A)
17. Harvard University, (2, 99.18; 22, 45.00)
18. University of Miami, (235, 42.97; N/A)
19. Princeton University, (10, 96.03; 21, 45.00)
20. Stanford University, (13, 93.62; 2, 83.00)

* The first two numbers in brackets represent *ranking* and *score* of a university according to the QS ranking of top universities in the world, and the last two numbers represent ranking and score of the school of engineering in these universities. N/A = ranking not available.

Appendix B

List of Universities in Canada

1. Royal Military College of Canada, (N/A; N/A)
2. University of Calgary, (165, 51.74; 151=, 19.00)
3. Carleton University, (401-450, 25.62; N/A)
4. Concordia University, (401-450, 25.56; N/A)
5. Dalhousie University, (212, 46.40; N/A)
6. University of McGill, (19, 89.25; 29, 43.00)
7. University of New Brunswick, (216, 45.60; N/A)
8. Memorial University of Newfoundland, (N/A; N/A)
9. University of Ottawa, (231, 43.54; 231=, 14.00)
10. University of Saskatchewan, (ranked in the top 20 schools in North America)
11. Schulich College, (N/A; N/A)
12. University of Toronto, (29, 84.29; 14, 54.00)
13. University of British Columbia, (44, 77.41; 30, 42.00)
14. University of Victoria, (241, 42.64; N/A)
15. University of Waterloo, (145, 54.73; 39=, 38)
16. University of Western Ontario, (164, 51.83; N/A)
17. University of Windsor, (N/A; N/A)

Appendix C

List of Universities in Saudi Arabia

1. King Abdul Aziz University, (401-450, 26.10; N/A)
2. King Faisal University, (N/A; N/A)
3. King Fahad University of Petroleum and Minerals, (255, 41.51; 258=, 13.00)
4. King Saud University, (221, 44.89; N/A)
5. Umm Al-Qura University, (501-550, 19.29; N/A)
6. Yanbu College, (N/A; N/A)
7. Al-Qassim University, (N/A; N/A)

التعليم والتدريب في مجال الآلات والآليات (دراسة مقارنة)

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المستخلص. كانت الآلات والآليات قد استعملت على الدوام كأدوات لتحسين حياة الإنسان وطريقة معيشته، كما بدأ الناس استعمالها بتحويل الموارد الطبيعية إلى أشكال وصور متعددة من الأدوات القديمة التي صنعها الإنسان. ولقد كان الحال مشابها في أحد أهم المجالات الأساسية للهندسة الميكانيكية ألا وهو الآلات والآليات، وهو مجال كان أظهر ما فيه اختراع العجلة. وكلما تقدم عالم الهندسة كلما ازدادت الحاجة إلى تعليم وتدريب مهندسي المستقبل على أحدث التطورات التقنية واستوجب تزويدهم بمهارات إضافية تتمثل في قدرات البحث والتطوير. تلقي هذه الورقة نظرة عامة حول الوضع التعليمي والتسهيلات التدريبية في مجال "الآلات والآليات" في دولة نامية كالمملكة العربية السعودية. أظهرت الدراسة أن المملكة تركز حاليا على مجالات مثل الميكانيكا، وعلم الحركة، وتصميم الآلات، وحركية الآلات، ونظرية الآلات التي تدرس في الجامعات بعموم المملكة. كما ناقشت الورقة الوضع التعليمي والتدريبي في جامعات المملكة مقارنة بمثيلاتها في الدول المتقدمة مثل الولايات المتحدة الأمريكية في مجال "الآلات والآليات". وكشفت الدراسة أن طبيعة العمل التدريبي المبني على المعمل ومدى تغطية المجالات ذات الصلة وطرق التدريس لهذه المقررات ذات التقنية العالية في الجامعات

السعودية تحتاج إلى مزيد من التحسين لتكون مضارعة لمثيلاتها في العالم. وحيث إن المملكة بدأت حديثا العمل في مجال "تقنية النانو" فقد تم إلقاء الضوء على تأثير ذلك على تصميم وتطوير البرامج المستقبلية المتعلقة بالآلات والآليات. وتخلص الورقة إلى توصيات ربما تساعد مخططي السياسات في مجال التعليم الهندسي بصفة عامة والآلات والآليات بصفة خاصة لمستقبل ناجح للدول النامية لمواكبة أحدث الابتكارات .

كلمات مفتاحية: الهندسة الميكانيكية، التعليم الجامعي، المناهج التعليمية، الآلات، الآليات، التقنيات.