Publications

Available Online

J. Sci. Res. **10**(2), 159-173 (2018)

JOURNAL OF SCIENTIFIC RESEARCH

www.banglajol.info/index.php/JSR

Improvement of Effectiveness by Applying PDCA Cycle or Kaizen: An Experimental Study on Engineering Students

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Received 6 February 2017, accepted in final revised form 6 March 2018

Abstract

This study mainly focused on developing skills on different field of perspective like software-based skills and interpersonal skills which will help an individual to become more proactive and efficient in their desired job field. In this memorizing based educational system students are not encouraged to learn new skills like software-based skills and interpersonal skills which are very much important to become expert and qualified individual in the corporate and competitive job field. The aim was to develop an effective method which will help the students to learn these necessary skills besides their regular course related study. It was focused on using this method by approaching on a gradual step by step procedure and developed it to solve the problem. It will save the time of the students and also make their fundamental knowledge strong on different software. A survey was conducted among the students from own university and got a satisfactory response from them. Most of them were looking for an effective process of learning without harming regular studies. This method will obviously help the students of our country to improve skills besides regular studies in a more effective way to be expert in their own field of specialization.

Keywords: Skill; Quality; Kaizen; PDCA cycle.

doi: http://dx.doi.org/10.3329/jsr.v10i2.35638 J. Sci. Res. **10** (2), 159-173 (2018)

1. Introduction

In this Hypothesis, the main presented topic is based on ‘Kaizen’. One can make himself highly skilled and qualified by approaching through a specific process. First, it was found out what skills are most important for an Industrial Engineer. A ranking of the skills was established on the basis of importance. A way was constructed through which students learnt to practice with real life application. For example, “Probability and Statistics” course was taught but it is fully theoretical and in the work arena Engineers have to imply

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it smartly and within short time. In this case, it is necessary to learn to work with some software which are very powerful and popular in solving statistical problems. Such as, MATLAB, MINITAB, Microsoft Excel etc. Those softwares were learnt through applying this developed process. Students under observation used these softwares to solve the reference books problems and took more assignments from the teachers which are similar to problems that will be faced in the practical workspace. They performed some group works and arranged presentations of the innovative works regarding to the particular software. Many intra department, inter department, inter university contests were arranged with the help of the teachers and administration. It was very much effective to learn how to perform activities more smartly using those software's. A club named 'Society of Computer Aided Designers RUET (SCADR)' has been formed to learn and teach Computer aided design related courses and softwares like Solidworks, Catia, Autodesk Inventor, Ansys workbench etc. This society is contributing a lot to develop sustainable skills in Mechanical, Civil, Industrial Design, Computer aided Manufacturing and simulation involving mass students and providing them training, seminars, contests, resource materials etc. So, a satisfactory achievement has been obtained from the group learning process, presentations and contests in a properly organized way which also builds up Qualities such as leadership, co-operation and confidence etc.

Kaizen is a Japanese hybrid word. "Kai" means change and "Zen" means good. Basically, Kaizen is for small incremental improvements, but carried out on a continual basis. According to Imai (1986), "KAIZEN" is the key to improve through Competitive Success [1-3]. Moreover, it means continuing improvement in personal life, home life, social life and working life [4]. Skills are necessary qualities for a student. "Quality is anything that can be improved, and that needs improvement". Kaizen is a process which leads someone to a permanent improvement gradually. Various skills are difficult to develop besides traditional courses of the university. But, there are almost 4 years which is enough time for a student to develop certain skills regarding which field he wants to be specialized. So, Applying Kaizen from the beginning it will be very easy for any student who have passion for something and want to dominate in the career as well as in the research field.

It will be continued besides studies for a long time. So, regular study will not be hampered. It is a sustainable way because, skills will be developed continuously and everything will be understood what is being learnt. By working in software, basic theoretical clear concepts will be achieved. So, result will be improved in University exams. Research capability will be increased. Imagination power and problem- solving capability within a short time will be improved. Job opportunity will be highly increased. In the job sector, higher authority will be impressed. So, getting promotions will become easier.

KAIZEN has been applied which is a continuous improving strategy towards a large achievement permanently. PDCA cycle is very important for the students because most of them don't know about the software [5]. So, first they have to be motivated for software learning. Some questions may arise "Is it very hard? Can they become expert? Will their

studies be hampered?" and etc. So, if they think about an efficient way without affecting the regular studies then Kaizen is an Optimum choice for all. Before starting this methodology, those who wanted to become skilled and get better jobs went to the training centers for learning software. It was costly. Moreover, a huge time was killed after passing. Remaining unemployed after passing an Engineering course is not seems good. But, in this method the 4 years of study period will be properly used and it is not so costly because everyone will learn by co-operating each other. This PDCA cycle process is very structured method and what should have done is early instructed. Instruction of learning from tutorial efficiently was also given. Self-learning capability is very much important for engineers. So, time for developing own strategy and imagination power is enough. As a result, a large amount of research works will be possible. This will increase the potentialities for higher studies abroad. Finally, Job opportunity will be increased and better jobs will be offered after passing the University.

2. Literature Survey

In our country the educational system is mainly theoretical based which emphasizes basically on memorizing the lessons, writing these alike written in books and getting good marks. The courses do not aim to develop the interpersonal skills which are very important for the job environment. Although, some practical courses and lab facilities are provided by Universities these aren't sufficient enough to keep pace with the rapidly growing High-Tech industrialized world. In the 21stcentury, the modern world is witnessing the technological revolutions in the industries but this traditional curriculum is not updating to meet the demand of new technology. So, students can't obtain the updated technological knowledge from this out of date curriculum. As well as, the lab equipment are not advanced enough to provide sufficient practical knowledge of the modern technology. Students are learning to operate and work with the dilapidated instruments and machineries which are not used in the Industries now. For example, Mechanical and Industrial Engineers are learning the traditional machine tools in "Shop Practice-I, Shop Practice-II, Production Process-II Lab" where the Industries use CNC (Computer Numerical Control) Lathe, Drill, and Mill etc. machines. Civil and Mechanical Engineers still make drawings and drifting by hand on the drawing sheets where the industries use updated powerful software like CATIA, Siemens NX, Pro-Engineers, and Autodesk Inventor etc.

Only a few works have been done in this topic of interest. In the year 1994; Dean and Bowen did a compact review on total quality management and Showed Kaizen module can be applied on any TQM process to make it easier in real life [6]. In 2003; Brunet and New did a compact review with detailing of the working model termed 'Kaizen' [7]. But this paper lags in detailing about sustainability management benefits of 'Kaizen'. Sallis wrote the book 'Total Quality Management on education' where he did detailing on applying Kaizen module on education sector [8]. Recently in 2017, Brunner did a research on Kaizen module on production management [9]. He found Kaizen to be very supportive

in industrial management process. Yamaguchi and Kono did a case study on standstill conditions in Kaizen activity and implemented this on two companies [10]. Found Kaizen model to be very effective in case of company's long-term business plans. Schwarz *et al*. carried out a survey analysis on application to Kaizen for the performance enhancement of two organizations was conducted [11].

2.1. Root cause analysis

Root cause analysis or fish bone diagram is a tool of Total Quality management which illustrates a process by showing the root causes and their sources. It is directly connected with KAIZEN because KAIZEN is also a tool of Total Quality Management. The fish bone diagram was developed by Ishikawa [12]. Fig. 1 shows the root-cause diagram from the investigations of Section 2.

As an Engineer, some specialized qualities must be possessed. The industries and organizations require many highly skilled engineers. If they have no idea about practical work sphere then they can't show better performance. Only theoretical knowledge can't make anyone highly skilled Engineer. In practical and corporate life, they have to face many critical situations, work with very complex projects, and handle the equipment (Man, Machine, Money, Materials) in a smart way. If they have Software based and Interpersonal skills they can:

- Complete the task in a short time using software
- Work in a smart way
- Solve problems very easily and efficiently with software
- Handle data and process information easily and accurately
- Get a perfect solution from software.
- Handle situations easily by decision making skills
- Communicate with others very smartly by verbal and non-verbal communication skills.
- Work in a team efficiently by team working skills.
- Handle the employees in a smarter way.
- Can deal with byers and other companies smartly.

All industries and organizations desire to get Employees who have characteristics and standard mentioned above. These characteristics will fulfil their satisfaction level and so, definitely skills are identified as quality.

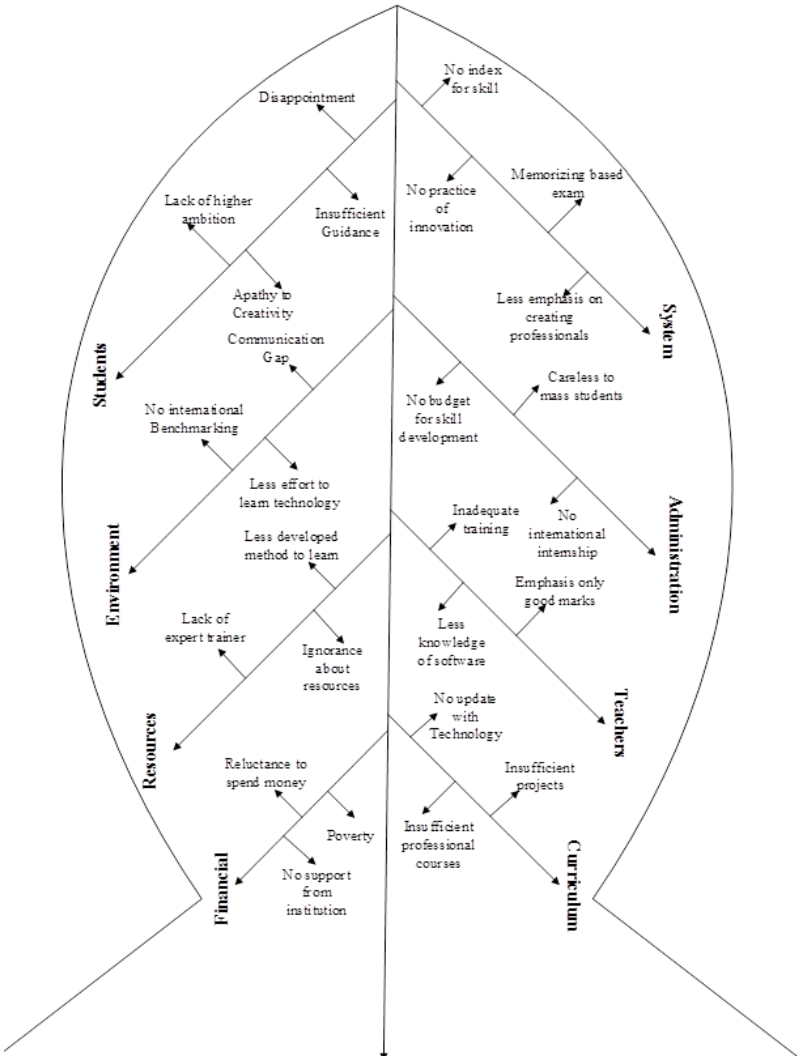

Fig.1. Root cause module (Fish-bone diagram).

3. Materials and Methods

3.1. Materials and basic methods

Kaizen aims at reducing losses in the practical work sphere and affect work efficiencies. By using a detailed and through procedure one can eliminate losses in a systematic manner using various Kaizen tools. These activities are not limited to production areas alone but can be implemented in administrative areas as well [13].

The PDCA cycle is a checklist of the four stages which one must go through to get from "problem-faced" to "problem solved". It is also known as Shewhart cycle [14]. It is a continuous quality improvement model consisting out of a logical sequence of four repetitive steps for continuous improvement and learning. The four stages are:

- *Plan:* Clarify objectives, Identify possible causes, Benchmark best practise.
- *Do:* Carry out trials, Analysis data to find how problem occurs, Find possible solutions.
- *Check:* Verify results, Training, Communication.
- *Act:* Review, Feedback, Make corrections, Presentations.

PDCA cycle process has been applied to develop both Software based skill and Interpersonal skill. Fig. 2 shows the PDCA schematic below.

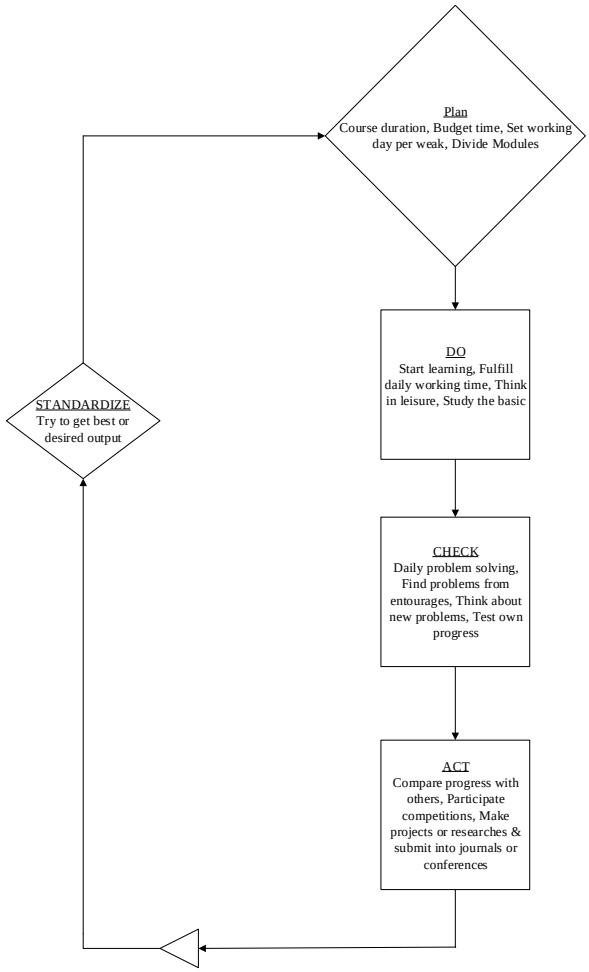

Fig. 2. PDCA cycle process.

3.2. Improvement of effectiveness applying PDCA cycle

First one should ask some questions himself

- What is one trying to do? – Set which skill is required to be developed and up-to which levels it is enough in undergraduate period.
- Will these skills help one in academic progress? – Which type of problems or projects one wants to accomplish and solve with the software are connected to textbook concepts or not.
- How can one learn it without affecting studies? – Reduce using social media, give-up unproductive gossiping, reduce playing virtual games.
- How will this skill help one in future? – Find the importance of the software, popularity, how many companies are using it etc.
- Is one willing to spend money for this? – If there appear some costs for learning the software or theories regarding that one will be able to spend money or not.

3.2.1. *Initial stage (planning cycle)*

This cycle emphasizes on planning for further procedures.

- *Plan:* Motivate enough to learn till the desired level. Set how many days in a week, how much times in a day it is possible to spend for learning the software. Then manage the time without affecting academic study time by reducing unproductive works such as playing games in phone, gossiping with friends etc.
- *Do:* Learn full time that have been budgeted. Don't lose motivation. Study the basic reason or theory from academic reference book and also from other famous books. Make connection of the learning with academic studies. Think about new problems in leisure period such as before sleeping.
- *Check:* Add a little time to check the learning to solve some easy problems. Test the learning way is correct or not. If one can't solve the problems then should learn it. Try regularly. Learn to solve problems by hard practice. Think about which problems regarding with academic studies can be solved with the software. Try to solve them. Check the progress through it.
- *Act:* Discuss about learning with some friends in holidays. Try to solve some big problems together. Make competition with them in each holiday. Arrange Intra department competitions. Record the mistakes & weakness.

3.2.2. *Root cause analysis cycle*

This cycle emphasizes on finding causes of faced problems and makes possible solutions.

- *Plan:* Make root cause analysis of the faults and weakness of solving the problems.
- *Do:* Learn software through realization with problems.

- *Check:* Resolve the problems. Try to reduce solving time. Make an efficient algorithm to solve all the tasks. Categorize problems. Verify whether the time is really reduced or not.
- *Act:* Participate in contests again. Try to make remarkable progress. Compare the progress with the champions.

3.2.3. *Research and developments*

In this stage checking the resources is much important before starting work so check should be performed before doing.

- *Plan:* Think about some innovation. Find some unsolved problems of real life.
- *Check:* Study about the problem. Collect data. Search about previous researches or projects connected with the problems. Explore a possible solution method. Verify collected data and data sources. The software has been learnt will be used or not in solving the problem efficiently, check it.
- *Do:* Make outstanding researches or innovative projects.
- *Act:* Submit research into journal or national or International conferences. Make a smart presentation of projects to the teachers or international exhibitions. These will ensure the skill of the particular software. It will also help as a certification or documentation of learning.

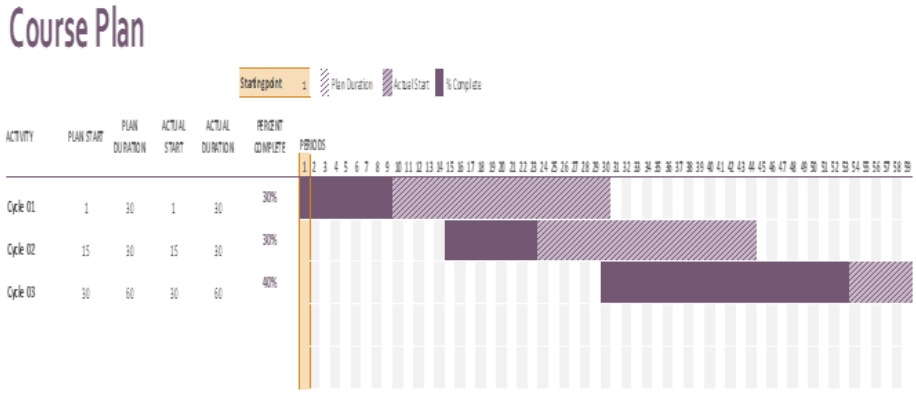

Fig. 3. Gant chart of experimented course plan.

Fig. 3 depicts the planning of the experimented course. The first step was to make the root cause analysis of the problem. The primary factors of poor professional skill were determined by Pareto analysis. Italian Economist Pareto stated "about 80% of the country's wealth is occupied by about 20% of the population" [15]. It is also popular as Pareto's 80-20 rule. This is also applicable in many spheres. About 20% causes are responsible for about 80% defects or problems. Here the 20% primary causes are

'Students', 'Resources' and 'Financial'. Ratings total 100 were given on the basis of importancein the Table 1 and Fig. 4 are a schematic given below:

Table1.Pareto analysis data table.

Causes/Reasons	Rating	Percentage
Students	30	30%
Environment	8	8%
Resources	16	16%
Financial	23	23%
System	10	10%
Administration	5	5%
Teachers	2	2%
Curriculum	6	6%

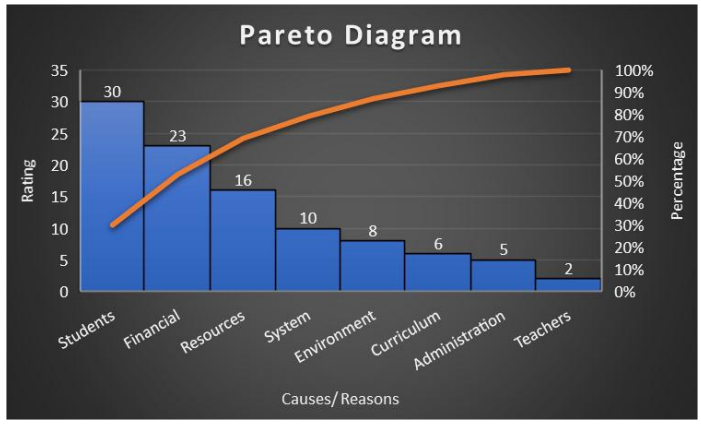

Fig. 4. Pareto diagram for Root-Cause analysis.

4. Results and Discussion

Our methodology was applied on about 100 students of 3rd, 2nd and 1st Years. They got positive response from everyone. 100% students want to develop skills. 3rd year students applied PDCA cycle for almost 3 months and they are able to become medium level skilled in different software.

4.1. Results from course related software learning

From the data analysis, it was found most interest on Solid Works and MATLAB most among courses related software. So, they applied our methodology to learn Solid Works first. A team from 3rd year started to learn by themselves from self-motivation because they had great passion and continuous learning besides their university courses and become skilled up to intermediate level. From their Check and Act phase of PDCA cycle their juniors were become benefitted. Many students from 2nd and 1st years got motivated from them and start to learn those software's. 3rd Year students arranged many seminars and presentation about their innovative works and projects. From them the juniors made

determination to learn those software's. The responses on different software and learning are given below in Table 2.

Table 2. Sample data table from field survey.

Samples	Course related software	Response rate	Professional software	Response rate
1	Solid Works	62.5%	Adobe Photoshop	54.2%
2	Siemens NX	4.2%	Adobe Illustrator	33.3%
3	Catia	16.7%	3D Studio MAX	25%
4	Autodesk Inventor	20.8%	Arduino	12.5%
5	MATLAB	41.7%	Adobe Premier Pro	12.5%
6	CPLEX	0%	Adobe Dream weaver	20.8%
7	Master CAM	0%	Blender	12.5%
8	ARENA SIMULATION	8.3%		
9	ANSYS WORKBENCH	0%		
10	Oracle Database	16.7%		
11	AutoCAD	29.2%		
12	LINGO	12.5%		

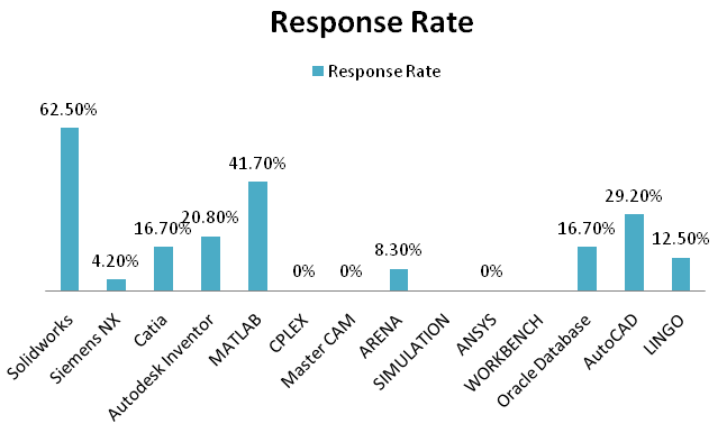

Fig. 5. Response rate from course related software learning.

A trend of software learning has started in our University. Many students found their passions and their hidden talent in which they can make outstanding success. A number of case studies and Innovative research papers have been made and these are ready to be submitted in various world class journals. Finally, a good communication has been established with many professionals of different working sectors from different industries. Thus, enthusiastic students were able to know which qualities they should obtain to get their dream job. Fig. 5 is the schematic presentation of field survey response.

4.2. Result from interpersonal skill development

From survey, it was found that everyone who took part in our survey were interested to develop all interpersonal skills they focused. They become highly motivated to develop their interpersonal ability to improve their personal growth and self-esteem. They found that people who are interested in our study are greatly adapted to their working environment and efficiently handle any challenging situation. Around 30% of them are get highly reputed in their institution for their positive attitude towards their work. Finally, by improving these skills, they found that they eventually satisfy the goal of our case study.

4.3. Results from professional software learning

From the data, we found that most students want to learn Adobe Photoshop, Adobe Illustrator and 3D studio max. So, a team was formed among some interested students. They followed PDCA cycle process and somehow managed to learn the software in a structured way. These processes made a permanent impact in mind and they do not forget anything what learned. They were able to make some money by freelancing to support their daily expenses.

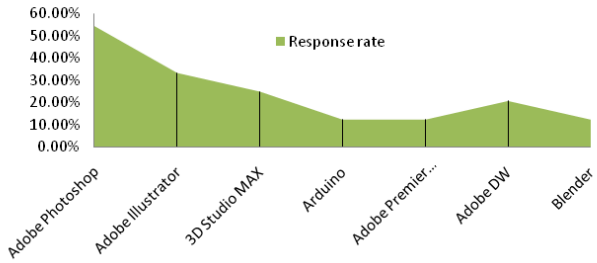

Fig. 6. Response rate from professional software learning.

Those software's' are also very popular in job sectors and industries. Some made a strong profile in freelance market and they were able to satisfy their buyers. Finally, the objectives have been achieved. Fig. 6 is the graphical image of response from professional software's. A significant increase of overall effectiveness has been achieved. Various results are shown in tabular form from Tables 3 to 8.

Table 3. Results from research publications.

Research Publications							
Journal Publications				Conference Publications			
Scopus Indexed		Others		National		International	
Before	After	Before	After	Before	After	Before	After
0	5	0	33	2	7	1	23

Table 4. Results from Professional certified courses.

Professional Certificates		
	Before	After
MATLAB certified	0	5
Solid Works certified	1	27
Autodesk certified	3	22
Supply chain certified	0	3
Professional Article reviewer	0	2

Table 5. Results from competitive competitions.

Competitive performance (prize winner)		
	Before	After
Inter University (National)	5	7
Inter University (International)	3	4
Intra Dept.	7	12
Intra University	17	25

Table 6. Results from freelance contribution.

Contribution in freelancing sector		
	Before	After
CAD/CAM	2	14
Graphics	10	25
Robotics	15	15
Signal Processing	3	7

Table 7. Results from Academic performance.

Academic Performance				
	Before		After	
SGPA	Below 3.00	Above 3.00	Below 3.00	Above 3.00
	73%	27%	48%	52%

Table 8. Results from arbitrary reasons.

Sincerity/ Higher ambition about life		
	Before	After
Depression	30%	11%
Drag addiction	23%	19%
Thirst for knowledge	44%	62%

The formula to determine increase in single Criteria of skill,

$$e = 100 - \frac{\sum_i \text{After} - \sum_i \text{Before}}{\sum_i \text{Before}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(a)}$$

For Overall increase of effectiveness,

$$\eta_{\text{overall}} = \frac{\sum e}{\sum n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(b)}$$

$$n = \sum \text{Criteria}$$

The result from calculation is given bellow in Table 9.

Table 9. Evaluation of incremental change in effectiveness.

Criteria	Increase in effectiveness
Research Publications	21.66%
Professional Certificates	13.75%
Competitive performance (prize winner)	0.5%
Contribution in freelancing sector	1.05%
Academic Performance	11.5%
Sincerity/ Higher ambition about life	5%
Overall	10.692% ≈ 11%

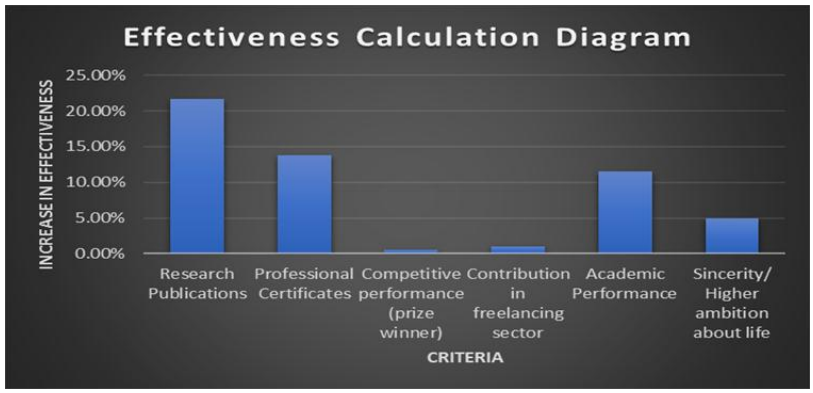

Fig. 7. A graphical relation between effectiveness and various parameters of the experiment.

5. Achievements

The achievements of experimented students of RUET after attaining this course are given below:

- A team was formed among 18 students of different years to Design and manufacture a "MARS ROVER" Robot. They were from different software skills and worked in sub teams to finish the project successfully. Finally, they were able to Design a "MARS Rover" Robot prototype and successfully run it in University campus. The Vice Chancellor and many Reputed Teachers were present and they highly appreciated the work of the Team. The name of the Team was "Team Ogrodoot". Ogrodoot-V4 runs at The Indian Rover Challenge (IRC)-2018, organized by Creation Labs, Vellore Institute of Technology, Tamilnadu, India and achieved the 6^{th} position [16].
- The news was published in some famous daily newspapers on 2nd January 2017. The team is aiming participation "University Rover Challenge" contest which will be arranged by the 'Mars Society' in Utah, USA [17].
- Another Team named "Team Crack Platoon" they have already participated in various national and international competitions organized in home and abroad with prestigious recognitions. They are the Regional Champion of Youth Fest

2016, Rajshahi. The team had been selected for the first round of Valeo Innovation Challenge 2016, France among 500 ideas from all over the world. They were also qualified as the second-round participant of SHELL ECO-MARATHON ASIA 2016, was held in Singapore. The team went to Quad Bike Design Challenge, India 2016 as the final round participant. That competition was organized by Fraternity of Mechanical and Automotive Engineers [18].

- Many students are participating in various debate contests and achieving prestigious awards [19].
- A contest named "Robolution-2k17" was held in Military Institute of Science and Technology (MIST) & a student from 2nd year stood 2nd Runner up in Solid Works Design Contest [20].

Many organizations are seeking volunteers from our University for their important functions.

6. Conclusion

This 'PDCA' cycle is a part of KAIZEN. The main target of KAIZEN is to achieve a sustainable result with very small investments. The primary duty of a student is to study regularly of his academic studies. But when the system and administration has no attention on students' professionalism or skills then it is very much important to take steps from self-interest to develop ourselves. To change a system is not so easy or depending on the administration will not be wise. But it is very easy to change ourselves for the sake of our own future. There is a lot of times besides our academic studies which we waste by doing fun, playing games, watching movies etc. This time can be invested for good purposes. Financial problem may be an obstacle but when unity arises then nothing is impossible. Each person's financial contribution made a large fund to buy resources or tutorials from internet. This is how 'PDCA' cycle made possible the skill development challenge and started a good trend to use time for our future. If it can be applied by all teachers and students then a large number of innovation and outstanding researches will be possible which can help our university to achieve good ranking in international index.

Acknowledgment

The authors would like to acknowledge M. M. Hossain (Dept. of Industrial & Production Engg., RUET), M. U. H. Joardder (Dept. of Mechanical Engg., RUET), M. I. Masud (Dept. of Mechanical Engg., RUET) and F. Rashid Rashed (Dept. of Mechanical Engg., RUET) for their undeniable support and help to conduct this research. The authors would also like to acknowledge the technical help and advice from M. A. Arefin (Dept. of Mechanical Engg., RUET).

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