Introducing the Conceptual Model of Industrial MOOCs (I-MOOCs) for Engineering Classes

Bringing applied knowledge straight into the Classroom

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***Abstract*— Engineering classes are operating today in the same format as they were fifty years back. The difference in the past decade has been the emergence of the Internet and its rapid usage right outside the walls of the class. Harvard University and MIT's path-breaking collaboration in initiating Massive Online Open Courses (MOOCs) has raised the global standard and reach of education today. The race is a long-drawn one, since we are no longer competing just to stand at the top as educationists, but rather to stand out in terms of the extent to which we can provide the best and most outstanding resources to our students in the face of a fast-changing world. But are we still going to follow what was given to us, or do we have a chance to start our own revolution? The answer to this lies in how we look at engineering education at this point in time. Engineering is the budding field of industrialists of tomorrow. So why can we not bring industrial experience right into our classrooms? The most effective method of learning a concept is to get a first-hand experience of its application. Such an experience would not just enhance the quality of our engineering classrooms, but also offer the students an unforgettable experience and the motivation to become efficient and responsible engineers of tomorrow. This paper presents a conceptual model of how to effectively implement this idea within the existing organizational structure, so as to implement a smooth transition to smarter and richer modules of engineering education.**

Keywords—MOOCs; Massive Open Online Courses; Educational MOOCs; Industrial MOOCs; Engineering Education; Education; Educational Model; Active Learning; Applied Learning; Practical Education; Industrial Education

INTRODUCTION

The term MOOC (Massive Open Online Courses) was coined in 2008 in order to name the open online course offered by the University of Manitoba, Canada. MOOCs became "an educational buzzword" in the academic community starting 2012. It was in the year 2001 that the very first Open Course Ware (OCW) was launched by MIT [4]. This can be called the first generation of MOOCs, since it was the budding stage of a greater educational revolution. The idea was to put up on the web all/part of the educational material that was used for the regular courses, permitting its use, modification and re-distribution by means of licenses. In 2012 the EDX initiative was launched. It was the brain child of two of the top universities in the world Harvard University and Massachusetts Institute of Technology (MIT), in the United States (US). Based on the improvements that were brought about during this stage, which is currently ongoing, it can be called the second generation of MOOCs. The idea was to take education to the global community of learners in the form of proper course modules that entailed certification upon satisfactory completion. The aim was to give access to high quality education to students across the globe irrespective of their age, race, gender, religion, nationality, etc.

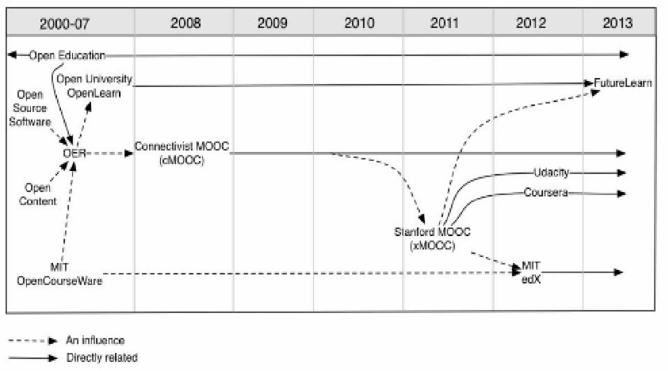

Fig. 1: MOOCs and Open Education Timeline [2]

Within just two years from then, MOOCs have reached millions of students across the world, living in more than 170 countries and the number is still growing. The MOOCs can thus be called as one of the largest educational ventures ever attempted in the history of mankind, with such incredible results within a short span of time. That is the power of the World Wide Web.

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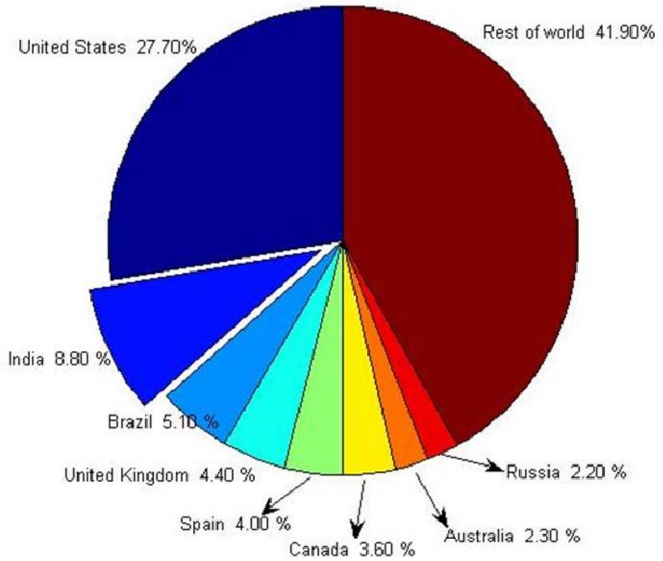

Fig. 2: Breakdown of Students pursuing MOOCs [2]

Although nearly 8.80% of the students pursuing MOOCs are from India (Fig. 2), very few Indian Universities participated in this revolution, with the exception of the Khan Academy initiative. In 2014, IITB (Indian Institute of Technology, Bombay) joined the EDX platform as a participant contributor to the ever-growing range of international course-providers. The courses introduced by IITB were mostly engineering courses especially designed for first year engineering graduates and considerably limited in its variety of topics. Except for IIMB (Indian Institute of Management, Bengaluru), no other Indian University or College has participated so far, especially at the EDX and/or Coursera platforms, intensively or extensively. Many questions can be raised thus, about the global standards of courses taught in classrooms across academic institutions located within India and what stops us from experimenting with our teaching methods.

The focus of this paper is on engineering education and the introduction of a method, which although inspired from MOOCs, is fundamentally different in nature and highly relevant in the Indian context. The major problem with engineering education right now is its old format and lack of practical updates and/or support from external sources to the textual study material. Students, who come out as engineers from these colleges, a majority of them, would soon be working for national and international industries and/or companies. If the teaching material and the methodology were to be made more accurate, it is essential that they are prepared with the same consistency of content as well as the context as the actual practice of these sciences in the real world. Universities like MIT carry out this idea consistently in the form of collaborative industrial projects and internships. The same system is smoothly functioning in the Indian scenario, but the question that this paper addresses is that of seamlessness of knowledge.

Some key aspects of updates to Engineering education in the classroom is worthy of consideration. Given that a new technique is developed in the Research and Development Unit of a concerned industry, how long does it currently take for it to be included as part of the curriculum? More importantly, once such a method is included how long does it take to get updated? If we are to have a more seamless collaboration between industry and academics, it is essential that both sectors work together within a systematic and collaborative framework. This is where Industrial MOOCs, or I-MOOCs, will help form the bridge between the two.

The main point of difference between an Educational MOOC and an Industrial MOOC is described in the following definitions:

1. **Educational MOOCs** – These are online courses that are prepared by the faculty from different academic departments of a College/University. These are meant for students who seek to learn the subject (mostly theoretical), as taught in the College. It is an online module where most lessons are conducted through video lectures that are recorded at a past date and then posted on the course dashboard at the respective website. These are primarily easy to understand courses, including some specialized courses, which can be followed by any graduate, post-graduate or doctoral level students. The courses are repeated over time and updated as per requirement. Reading materials are also provided for the purpose of studies. Exams are conducted mainly by means of quizzes and peer assessments. It works like any other average college classroom education, but on a virtual platform.
2. **Industrial MOOCs** – It is proposed here that activities and innovations that are carried out in laboratories and industries, across the world, can be included as part of the curriculum in a format that is similar to educational MOOCs. Theoretical topics can be elaborated further, by means of these live sessions, where students can witness and question the methods being adopted at the industries for specific engineering applications, by means of live concurrent teleconferencing sessions. Professionals on field will collaborate with the academicians to explain systems and processes in detail to students and help them get a broad as well as detailed perspective of the field of engineering. All this being an integrated part of the online platform, will include online quizzes related to the sessions and other scheduled class work that can be carried out by means of the online course dashboard, operating on individual college/university websites. Assessments and evaluations of the students can be performed online, thus saving a lot of time, otherwise wasted, in lengthy academic procedures.

LITERATURE REVIEW

MOOCs have been extensively studied and their purposes, methods and reach have been thoroughly analyzed by means of systematic reviews [4]. In the beginning, open courseware was just a tool aimed at a specific population of the academic community. It was tailor-made for a certain group of students who would be able to follow the material (based on their course specializations) and for the educators to use the same platform to teach and improve their materials for the classes [3]. But, when its reach breached the boundaries of institutional structure, MOOCs became revolutionary phenomena in distance education. However, there are conflicting views on this which looks at MOOCs as nothing more than a movement that has already died, or that what it is currently offering is a molecular version of education [5]. But the reality is MOOCs are still a highly valuable resource for the students and innumerable people are signing up for these courses each passing day.

Considering the needs of Engineering Education today, MOOCs still have considerable limitations. Hence, innovative changes in MOOC or its applications [8] will offer new solutions to the existing needs of the classroom [1]. One such approach is suggested by means of this paper; however, it is merely an extension of thoughts, already expressed, of inculcating MOOCs in traditional classroom education and to enhance the quality of teaching methods and study material currently being covered [7].

According to the IEEE CS 2022 report, MOOCs are one of the 10 technologies that could revolutionize the world by 2022 [2]. This can happen if and only if the MOOC phenomena innovates its own methods and seeks constant change, rather than grounding itself in its recent achievements. We still haven't been able to address some of the fundamental issues that face an Engineering class today. One such issue which is addressed here is a strong and seamless integration of industrial application into academic curriculum.

OBJECTIVES

The conceptual model of Industrial MOOCs (I-MOOCs) proposed here intends to fulfill the following objectives:

1. To enhance the quality of Engineering Education by inculcating application based instruction into the curriculum
2. To allow students to work in mutual collaboration with the Industrial teams, therefore improving both application and learning seamlessly and simultaneously
3. To offer a collaborative platform for innovation, research, education and training by promoting mutual co-operation between academic and industrial/organizational teams

CONCEPTUAL MODEL (OUTLINE)

The conceptual model proposed in this paper is cyclic in nature. What we propose here is a new generation of MOOCs since the model is fundamentally different in terms of its content and the context of its creation. The overall model of introducing this concept is as follows:

A. *Team Formulation* – It is important to assign high quality teams with multidisciplinary capacities for the purpose of designing Industrial MOOCs. Such teams will consist of both academic and industrial experts who will work together to design the most relevant content.

B. *Content Identification* – Topics have differential relevance to industrial application. Hence, it is the job of the teams to identify the right content and then connect it well with the resources that can be obtained from the industry.

C. *Content Integration* – Resources that seem useful for the students may or may not be relevant to their educational needs. There is a need for a good understanding in regards to what is suitable amid the available resources and what it is that will help to make student learning within the classroom easier. Thus academically relevant content can be offered only by integration of these factors within the design process of the material.

D. *Content Development* – Development of the content needs to be carried out with finesse. High quality digital resources and techniques of filming, video-editing, audio recording and enhancing should be used for the purpose. This when combined with the richness of the content will then make a lethal combination for a highly effective MOOC.

E. *Content Enhancement* – By adding simulations, models, charts, references, academic and expert profiles, textual reading material, maps, images and many other forms of representation, the actual recorded content can be enhanced into something much more interesting for the students.

F. *Content Broadcast* – The fresh content is now systematically digitalized by means of a given IT platform and made available online. Students can now sign-up to this program across the globe and access the resources. The focus will be on engineering students who have enrolled in a relevant degree program and would like to have an exposure to the applications of their course content. The material will be treated more as a supplementary resource and will be updated and improvised with time.

G. *Online Collaboration* – This platform will allow collaboration on multiple levels. Course teams in other countries can follow the example and add to the material over time. There can be a methodological collaboration and such innovative projects undertaken between industries can also be included as part of the MOOC. Engineering students in one country can collaborate on projects being undertaken by the industries which are located in other countries. Thus saving a heap of time which is usually wasted in physical travelling, accommodation, etc. Institutions too can work together on generating new educational technologies and course materials on the same platform.

H. *Test and Evaluation* – After the courses are offered, the students can be tested online and their academic understanding can be evaluated. This will give an idea to the MOOC creation teams about the actual impact of the courses on student learning.

I. *Feedback and Assessment* – Feedback can be collected through the portal of the student's opinions about the MOOC. This is an essential part of the design process since it will enable the teams to know the pros and cons of the program and what more can be achieved by means of this model.

J. *Change Integration* – The platform on which Industrial MOOCs will be hosted should be a highly flexible programming regime that can adapt to the changing times and needs of the students, faculty as well as the industrial experts. Integrating new parts to the model should be easier and anticipated while formulating its executive framework.

K. *Re-Launch* – Once in a few months, the material has to be revamped based on practical changes occurring in the field of expertise. The MOOC teams will have to be actively involved in conversation with each other by means of the collaborative online platform so that both sides are always updated on changing needs of the students. Innovation, which is the highest priority of the initiative, has to be a seamless undertaking on part of all sides involved in it.

COMPARATIVE ANALYSIS

It is important to understand the comparative benefits and non-benefits of the proposed model in light of the currently operational educational MOOC system.

i. Source of Content:

a. E-MOOC: The current model has academic institutions as the main source of its content. Other parallel sources exist, but they are not very prominent in their engagement with the model.

b. I-MOOC: The proposed model has two main sources of content: 1) Academic institutions and 2) Industries/ Organizations. It is generally agreed that content from both these sources is of importance in the context of Engineering Education, making it different from instruction in other fields of science, and hence such collaboration can be much more beneficial than the E-MOOC model.

ii. Model Characteristics:

a. E-MOOC: Flexibility of time, place and student background is one of the main characteristics of the current model.

b. I-MOOC: The proposed model has a certain indirect restriction on the academic background of the student (since it will not be easy to follow for students who are not enrolled in engineering or related fields), however, the scale of the resources that are made available are richer than the current model in terms of its application base.

iii. Scope:

a. E-MOOC: The scope of the current model is mainly academic and it is, at this point, incomplete in terms of future possibilities that are on offer within the platform. For example, once the course is over the student is assigned a certificate of completion and the module ends without any further opportunities of involvement of the student with the concerned institution within the platform.

The student in this case is not involved as an active participant after the course is over. He/she does not have an opportunity to engage deeper with the content and its source with the help of real-time collaborations.

b. I-MOOC: The proposed model overcomes this by having an ongoing and seamless integration of academic and industrial resources. The information is active in nature since it is constantly updated with time and as per the student requirements. Feedbacks are constantly sought and improvements are made on the basis of valuable suggestions and other technological developments.

Students enrolled in I-MOOC can be active contributors alongside the MOOC teams, through the duration of the course and afterwards. This way, the knowledge gained by means of the course is brought to the field through the platform, and possibly can be extended to real and offline partnerships, thus outreaching and thus expanding the current model.

iv. Involvement:

a. E-MOOC: The students are involved at a fairly good level in the current MOOCs and they contribute to the discussions and peer assessments during the course of their study. However, their involvement is limited to the small academic team and does not reach a larger audience in the field of study, outside of the platform.

b. I-MOOC: Students (especially those enrolled in Engineering courses), by means of the I-MOOC can be involved with a wider audience in the field. Since both academic and industrial experts are part of the course preparation and seamless integration processes within the platform, it offers the students to converse with the best minds working on real projects, in real time. The contribution of these students might entail the possibility of integration into a larger pool of systematic, scientific and innovative knowledge.

v. **Richness:**

a. E-MOOC: Content is rich mainly in textual resources and information and other supplementary sources like recorded classroom lectures, promotional videos, articles, images, maps, etc.

b. I-MOOC: Content here is rich in terms of its frequent updates, coverage of real-time project undertakings by means of video, audio, etc., including all the textual and online materials that E-MOOCs currently offer.

vi. **Stability:**

a. E-MOOC: These are stable models; however, they are not seamless in nature. They have starting and end points that act as limitations for the students who want to access the resources in real-time and want to collaborate in practical projects.

b. I-MOOC: The proposed model is stable as well as seamless in terms of its content, since old content is frequently updated keeping in mind on-field developments. Students can be consistently involved with the portal and be active learners and innovators.

vii. **Sustainability:**

a. E-MOOC: This model currently does not entail long-term sustainability, since its updating patterns are inconsistent with the growing availability of many relevant sources if information.

b. I-MOOC: This model is designed keeping in mind its need for change with the changing times. It can easily be updated and integrated with new models of functioning, thus making it a highly sustainable model for the student community.

viii. **Future Advancements:**

a. E-MOOC: The current model is trying to offer seamless education by means of courses that can be joined and pursued as per the time availability of the student. However, such a model does not entail institutional certification of students at this point. This may possibly change in the coming years.

b. I-MOOC: The proposed model, however, is a much more advanced version of the current generation of MOOCs and comes with an inherent tendency to adapt to change and improvements in the future. Since it will be part of the institutional-industrial cluster, it can easily integrate dual-certification of qualification, as gained by the students.

CHALLENGES

One of the key challenges that this model faces is key policy changes within industrial and organizational structures, with respect to opening its doors for seamless real-time educational initiatives with academic institutions. Sharing of these resources need to be freed from the Intellectual Property Regulations which these organizations might impose on them. A third-party intervention (from the central government) might be required for a large scale initiative of this kind to take flight. A sound grounding of the project is needed in order to ensure that the application of this model reaches many engineering colleges within the country.

SCOPE

Educational institutions and industrial organizations are known for their highly bureaucratic approach and it can be more of an obstacle for MOOC integration than an advantage [6]. By means of I-MOOCs we are offering a solution to students who want to learn across these walls. I-MOOCs are meant to act as bridges that can give students important access points to the real and ever-changing sources of knowledge in the Engineering Sciences. However, it is suggested here that in order to see the practical implications of the model in real classrooms further research is required.

CONCLUSION

I-MOOC model, as proposed here, is a highly sustainable and innovative model for the Engineering classrooms of today. It has important advantages to offer and many obstacles to overcome. The process has to be slow and steady in implementation. The concerned partners need to be brought together with an aim higher than organization, which is flexibility and seamlessness. Actual use of their knowledge on field will help make student experience highly interesting and relevant. Students of today who will become engineers of tomorrow are important resources for our country and hence it is undeniable that we should do whatever we can to provide the best model of education for them, in order for all of us to have a better tomorrow.

REFERENCES

Desai, D., "Usage of Online Educational Courses by Undergraduate Engineering Students in Karnataka," Technology for Education (T4E), 2013 IEEE Fifth International Conference on , vol., no., pp.200,203, 18-20 Dec. 2013 doi: 10.1109/T4E.2013.54

Iqbal, S, Zang, X, Zhu, Y, Chen, YY, & Zhao, J. (n.d.). On the Impact of MOOCs on Engineering Education. Retrieved from http://www.researchgate.net/profile/Sajid_Iqbal5/publication/269854019

_On_the_Impact_of_MOOCs_on_Engineering_Education/links/5497f13e0cf20f487d319788.pdf

Liyanagunawardena, T. R. (2012). Information communication technologies and distance education in Sri Lanka: A case study of two universities (PhD Thesis). University of Reading, Reading.

Liyanagunawardena, TR, & Adams, AA. (2013). MOOCs: A systematic study of the published literature 2008-2012. The International Review …. Retrieved from http://www.irrodl.org/index.php/irrodl/article/view/1455

Morris, S. (2014, November 18). A Misapplication of MOOCs: Critical Pedagogy Writ Massive - Hybrid Pedagogy. Retrieved May 15, 2015, from http://www.hybridpedagogy.com/journal/misapplication-moocs-critical-pedagogy-writ-massive/

Perelman, LJ. (2014). MOOCs: Symptom, Not Cause of Disruption: MOOCs and technology to advance learning and learning research (Ubiquity symposium). Ubiquity. Retrieved from http://dl.acm.org/citation.cfm?id=2591680

[7] Tsai, FS, & Wong, KH. (2013). The State of Massive Open Online Courses (MOOCs) in Engineering Education: Where do we go from here? Proc. 120th ASEE Annu. Conf. Expo. Eng. Edu. Retrieved from http://www.asee.org/file_server/papers/attachment/file/0003/3914/6416.pdf

[8] Yixing, X. (2014, June 1). The Flipped Classroom Method in Programming Courses Based on MOOCs Pattern--》Journal of Hangzhou Dianzi University (Natural Sciences) 《2014年06期. Retrieved May 15, 2015, from http://en.cnki.com.cn/Article_en/CJFDTOTAL-HXDY201406023.htm

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Thinkers in My Classrooms

Teaching Critical Thinking – Deductively

Abstract—One of the paradox about humans thinking is that they are not simply the only "logical" animal, they are also the only "illogical" animal among all. They are the only animal that uses meanings —ideas, concepts, analogies, metaphors, models, theories, and explanations —to make sense of things, to understand, predict, and control things. They are also the only animal that uses meanings to negate, contradict, and deceive itself, to misconceive, distort, and stereotype, to become dogmatic, prejudiced and narrow-minded. Humans are the only animal whose thinking can be characterized in terms like clear, precise, accurate, relevant, consistent, profound, and fair; they are also the only animal whose thinking is often imprecise, vague, inaccurate, irrelevant, superficial, trivial, and biased.

Critical thinking makes sense in light of this paradoxical dichotomy. Humans shouldn't simply trust their instincts. They shouldn't unquestioningly believe what spontaneously occurs to them. They shouldn't accept as true everything taught as true. They shouldn't assume their experience is unbiased. They need to form, they are not born with, intellectually sound standards for belief, for truth, for validity. They need to cultivate habits and traits which integrate these standards into their lives. It is possible to achieve this by learning traits of Critical Thinking. Critical thinking is a trainable skill. This paper is case-study of the endeavor to teach these skills -deductively to Ist year Engineering students. The multi-disciplinary and radical approach in terms of content and methodology has created inquisitive students with mind more open and thinking more precisely. The papers also show case the evidence of this methodology, which is successful in inculcating the skill and ability to think critically.

Keywords—critical thinking, trainable, skills, engineering students.

Specific Skills	Core Skills	Personal Characteristics	Communication Skills
• Database knowledge	• Self confidence	• Business ethics	• Listening skills
• Spreadsheet knowledge	• Critical thinking	• Professionalism	• Speaking skills
• Word processing knowledge	• Creative thinking		• Written communication
• Ability to adapt to changing technology	• Interpersonal skills		
• Technical skills	• Leadership skills		
• Mathematical skills	• Experience with real world problems		

Need of the Hour

According to Forbes magazine, among the 10 most critical job skills to parlay in job search, Critical Thinking (found in 9 out of the 10 most in-demand jobs) is the most desired one [1]. They have defined this skill as, "using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems". David A. Garvin has said that the need is to sharpen thinking skills, challenging assumptions, having multiple perspectives [2].

Issues and Concerns

Education as panacea that can cure problems of world and can break the shackles of poverty, crime, unemployment and so on is always portrayed. Such expectations from the formal education system is crumbling down the belief of the practioners, teacher, students and industry alike. The workplace is devoid of critical thinkers and colleges are practicing learning, bereft of spurs that can trigger critical thinking skill [3]. One survey (1999) graphically indicated employers' satisfaction for graduates job skills which are desired by the them for hiring. Skills are considered into four main elements, that is specific skills, core skills, personal

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characteristics, and communication skills under which skills like ethics, Critical thinking, ability to adopt to changing technology and so on are chalked down[4]

Thus the dynamicity of the 21stwork-culture, employee diversity and demands of multi-tasking ability demands Individuals to have ability to adopt and adapt. [5]

It is increasingly clear that graduates need to clearly distinguish between clarity vs. clarity; precision vs. imprecision: specificity vs. vagueness: accuracy vs. inaccuracy; relevance vs. irrelevance; consistency vs. inconsistency; logicalness vs. illogicalness; depth vs. superficiality; completeness vs. incompleteness [6]. Higher Order Thinking Fig Fig 1: Skills under four factors skills is emerging as the magic potion for the graduates having degree but still not employable.

The Solution

Higher Order Thinking Skills are defined in three precise manner [7]. (1) HOTs as transferable skills (2) Skills in terms of critical thinking, and (3) skills that helps in problem solving.

Thus critical thinking category encompass thinking which is reasonable. It is also reflective thinking that guides thinker to decide what to believe or do'[8] . It also means artful thinking, comprising rational, inquiring and exploring, perceiving and defining, associating and involving, exploring intricacy, and reconnoitring different perspectives [9].

The empirical research has again and again reinforced the explicit, direct instruction of these skills [10].Understanding that aspiring engineers as a critical thinker can overcomes the barriers in thinking, and understand the limitations of an assumption and its implication; an inference and conclusion; arguments - sound or invalid; opinion vs facts; information sieving among other ambiguous and arbitrary thought processes thus achieving the intellectual standards comprising empathy, humility , fairness, among others traits. It was felt a course of Critical Thinking for UG level of engineering program should be administered deductively. The curse was proposed in one of the premier engineering college of western India. The need for the course was reinforced during the Internal Quality Assurance Meetings (IQAC) the highest steer committee of the college comprising various stakeholders of the institute. It was felt that the environ created by this course will inculcate in them thinking about thinking.

The Innovation

A course Critical Thinking was designed by in-house faculty in consultation with experts after going through various studies and surveys indicating the need like problem solving, logical and rational thinking, clarity of thoughts, among other graduate attributes. The course was passed through various academic bodies of the university and then was offered to the Ist year students of all branches (EC, IC, IT, CSE, Civil and Chemical). The teaching scheme is one hour lecture per week.

The course comprise interdisciplinary approach and is judicious mix of literature, philosophy, logic, reasoning and technical content.

Salient Features of the Course

The syllabus of the course was well researched and learning outcomes were well-defined and tangible in nature. With learning outcomes as ;

By the end of this course students will

• be better decision makers

• be able to evaluate facts in an argument

• learn Art of Questioning

• be able to derive truth, ambiguity, vagueness and fallacy in arguments

• According to Socrates, the unexamined life is not worth living. Students will discover that many questions have no clear answers. While one strives for certainty, often the best one can do is obtain a reasonable degree of probability. This will help them crack their competitive exams where many answers are plausible.

The syllabus covered

- Blooms Taxonomy
- Thinking about information and emotions, truth and knowledge
- Recognizing arguments
- Inductive and Deductive Reasoning
- Analyzing defects, fallacies and avoiding them
- Reasoning & elementary argument analysis and organized thinking

Pedagogy of the course was also very innovative in nature and active learning was employed along with blended leaning for the administration of the course. The course pedagogy involved lectures, videos, TED talks, discussions, assignments, case study and presentation of case study by students on Lack of Critical Thinking in Technical Disaster and a movie '12 Angry Men'.

Some of the case studies presented by the students included Challenger Space disaster; Chernobyl

Nuclear Disaster; BP Oil Spill; Kansas technical disasters among other disasters

The learning of these presentations were to make them understand and realize that disaster is an event but the process of the same starts very early when attributes of thinking were ignored.

The classroom teaching involved discussions, debates, braining-storming, challenging the beliefs and assumptions, arguing and differentiating between argument and disagreement/valid and not valid /sound and cogent arguments.

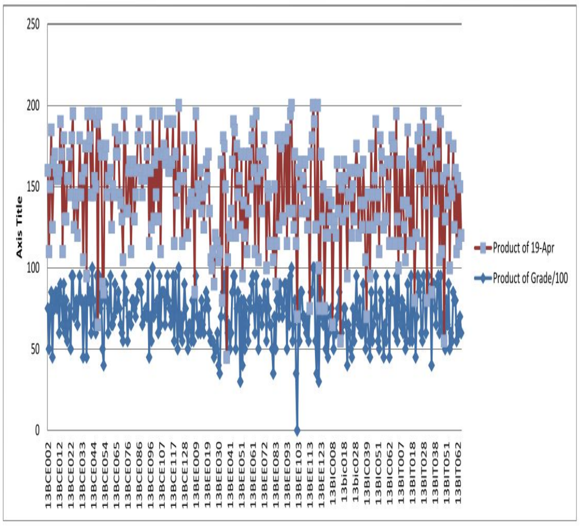
The course was evaluated by formative and summative assessment.

The Diagnostic Test

The Pretest was held on January 24, 2014 and a standard CT test from Cornell Critical Thinking Test Series was designed on Moodle for more than 400 students. Other student deliverable included class-room interactions, discourses, class- room conversations, journals entries, assignments submissions, viva-voce et al.[3]

The outcome of the course was judged by the diagnostic test consist of pre-test and post –test. The test was conducted on the very first week of commencement of the course and post test was conducted on the final week of the course

The Post Test was held on April 24, 2014 with same students and same standard test.



The result as indicated by the graph shows clear shift of thinking process of the students.

Fig:2 A sample graph of pre-test vs post-test performance

Concluding Remarks

The student who were administered this course are clearly more forthcoming, clear in thinking and well-articulated, research has shown that student do well and get well motivated when they know that they are learning how to practice critical thinking skills.

It was felt by other teachers of the institute that they keep on asking - Why, How and What and they don't hesitate to challenge the preconceived notion.

The survey and these intangible results indicated that it is possible to teach critical thinking skill by deductive method. In fact various research studies have shown that direct method of teaching critical thinking yields good result

It is also possible to instil Art of Questing in the students

The untraditional method of teaching-learning and evaluation can make student engagement interesting and effective.

References

[1] http://www.forbes.com/sites/meghancasserly/2012/12/10/the-10-skills-that-will-get-you-a-job-in-2013/ retrieved on May 8, 2015

[2] https://hbr.org/2010/01/how-leaders-should-think-criti/

[3] MISHRA, Richa; KOTECHA, K.. Defining Learning Outcomes of Co-Curricular Activities: Integrating Desired Commonalities. Journal of Engineering Education Transformations, [S.l.], p. 286-291, jan. 2015. ISSN 2394-1707. Available at: <http://journaleet.org/index.php/jeet/article/view/59358>. Date accessed: 30 Mar. 2015. doi:10.16920/ijerit/2015/v0i0/59358.

[4] Paranto, Sharon R., Mayuresh Kelker (1999), Employer Satisfaction with Job Skills of Business College Graduates and Its Impact on Hiring Behavior, Journal of Marketing for Higher Education, Vol. 9(3), The Haworth Press, Inc., New York, USA.(Fig 2)

[5] R Mishra, K Kotecha,(2012). Teaching Communication Skills Student Engagement Through Blogging "International Journal of Humanities and Social Sciences (IJHSS) 2 (2), 4

[6] Paul, Richard, and Linda Elder. "Critical thinking." The Foundation for Critical Thinking (2008)

[7] Brookhart, S. (2010), How to Assess Higher Order Thinking Skills in Your Classroom, ASCD, http://www.ascd.org/Publications/Books/Overview/How-to-Assess-Higher-Order-Thinking-Skills-in-Your-Classroom.aspx

[8] Norris, S. & Ennis, R. (1989), Evaluating Critical Thinking, Pacific Grove, CA: Midwest Publications

[9] Barahal, S. (2008), Thinking about Thinking: Pre- Service Teachers Strengthen their Thinking Artfully, Phi Delta Kappan 90 (4)

[10] Hattie, J. (2009), Visible Learning: a Synthesis of Over 800 Meta-Analyses Relating to Achievement, Oxon, OX: Routledge

Innovations in Evaluation: An Integral Part of Outcome Based Education

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***Abstract*— Education in India in 21st century demands innovations in the evaluation methods with the emergence of Outcome Based Education (OBE). Lots of Research is already done in innovations in teaching and learning methods, but very few literatures on the innovations in evaluations are available. The paper discusses various innovative methods for the evaluation of students. The pros and cones of traditional exam and the new methods are also discussed. A survey on the various method is carried out and the results of the same are also presented.**

***Keywords*— Open book exams, Outcome based education**

I. Introduction

21st century education is almost changed from traditional chalk and board to video projector. Lots of other innovations are also proposed to improve the teaching learning process. [1-3] from olden days of schools, examiners prefer the traditional written exams for the evaluation of knowledge gained by students. In traditional exam system, there is a midterm exam of about 50 marks is conducted after half semester is over and at the end of semester 80 or 100 marks exam for the full syllabus is conducted. In all the exams students are supposed to write the answers of the questions asked by the paper setter. Moreover, students are not allowed to carry any learning material or any electronic gadgets with them inside the exam hall. The exam timings are also fixed and are decided by those who will not be taking that exam.

The modern Outcome Based Education propose many innovations in the class room teaching and self - learning.[4-5] Less emphasis is given on the evaluation of the students who are forced to learn as per OBE. Does the traditional exams suit the modern OBE? Are there any other methods to carry out evaluations? Are the new innovative methods, if any, satisfy the evaluation criteria? Are the students ready for the new evaluation method? Are the teachers ready for that too? The paper discusses the answers of some of the questions listed above.

The rest of the paper is organized as follows: Section II discusses different methods and its pros and cones on the education and education system. Section III presents a discussion on a survey conducted on various evaluation methods and results of the same. Finally, the paper ends with the concluding remarks.

II. Evaluation Methods

There are various methods of evaluation. Each method is elaborated with its pros and cones.

A. Traditional Written Exams

Written exams are very popular way of evaluating the progress of students.[6] The little modifications made in such kind of exams are continuous evaluations or change in the marking patterns. In continuous evaluations, more than one exam is conducted at regular time interval and the final evaluation is based on the total or weighted sum of all the exam marks. The very obvious advantage of this method is that the students and teachers are well acquainted with this method and they don't need any extra care at the time of execution of exam. All the questions asked are clear and have specific answer to them. An evaluator can easily compare the performance of all the students based on the answers as the expected answers are known in advance.[6] The marking scheme is also fixed and all questions carry some predefined marks. Overall it is a safe game to play on the part of the evaluator. On the part of student also the traditional method is not disadvantageous as they need not to do anything new that they are not aware of. However, the traditional method of exams is not suitable in new education systems due to several reasons. Normally, teacher takes some particular subjects every year and the same teacher draws the question paper for the subject. The repetition of the paper setting work spoils the novelty of the teacher in drawing the papers. The same teacher cannot bring newness to the paper every time. Almost every five to six years the questions are repeated in the question paper. Students have the tendency of referring the old question papers. If one refers the question papers of last five years, then can easily predict almost 40% of questions, which is the passing marks for any exam. This problem can be overcome by changing the subject taught by a teacher every two or three years. If every two or three years a teacher changes the subject then cannot develop the competency for that subject. Moreover, there are specific types of question can be asked in the written exams. Students normally refer to the old question papers and get the idea of what kind of questions are generally asked. This will make the exam

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ineffective. Moreover, students only remembers the concepts learnt in the subjects and do not learn the application of the subject as they never find an opportunity to apply the concepts practically. The traditional written exams tend to test only theoretical knowledge gained by the students.

B. Viva or Oral Exam

Other than written exam, viva or oral exams are also conducted for the evaluation of students. [7] Mainly viva are conducted as a part of regular evaluation with written exams. Only viva are generally not conducted for the evaluation. Viva are conducted in groups. Two or three students are examined at a time by a group of teachers or an individual teacher. The session does not last for more than 15 to 20 minutes. Teacher asks 10 to 15 questions from the full content of the subject. Few questions are not ample to judge the competency of student in any subject. More questions are difficult to ask as all the answers may not be given orally. There is not adequate opportunity to the student to present his/her views in the short time of viva. Teacher also has very less time to judge the student, which makes the unfair evaluation of student if only viva or oral exams are conducted to judge the students.[8-9] Viva can be used with written exams to make it more effective.

C. Presentation Based Exams

Presentation examinations is one of the methods used by teachers to evaluate the students. Using this method the teacher can not only judge the competency of student in the subject, but also the communication skills, presentation skills and level of confidence as well. Viva is normally used for the evaluation of Seminar, Project or Case Studies. Any subject where traditional class room teaching has not taken place, the presentation can be used as a method for evaluation. It consumes less time for evaluation, less preparation on the part of teacher is required and provides an easy mean to judge the presenter. The main problem involved with this method is that it cannot be applicable to the subject where lots of contents are to be delivered. One cannot present the whole content of any subject in single presentation effectively. Such presentation requires large amount of time and for such large time the teacher does not enjoy the process of evaluation. Adequate amount of time can be given to presentation only if the number of students to be examinee are less. If a class of 60 or 120 is to be examined then presentation based exam is not an effective method as it is cumbersome for the evaluator to listen to many students at one go [10]. Every teacher has some prejudice for every students. The impression of student, on the teacher, also has an impact on the evaluation of Viva, which may be advantageous to some students and not to others.

D. Open Book Exams

Modern universities advocate the Open Book Exam to reduce the so called ‘burden of exams’ on the students [11]. In this kind of exams students are allowed to carry the material related to the subject to be evaluated in the exam hall. The exam will be written exam only, but with supporting material allowed during the exams. It is quite difficult to invigilate for such exams as students may pass on the material to other students, which leads to unfair means in the exams. In some cases students are allowed to carry only class notes given by teachers or one or two books related to the subjects, which are identified in advance or photocopy of three to four pages written by students prior to the exams related to the subjects. This method seems promising on the part of students, because students can learn while they are appearing for the exams. Student must know the full content of the subject before the exam so that the time is not wasted in finding the appropriate content to answer the questions during the exam. In this evaluation method the burden may increase on the teacher as teacher has to ask the questions whose answers are not obvious and directly available in the material allowed. Teacher has an opportunity to ask innovative questions and students have the opportunity to apply the knowledge gained during the class. Students will also learn to apply the available connect to a specific problem. Teacher competency of the subject plays a vital role in this kind of evaluation.[12] Teacher can ask the question of any complexity, but on the other hand teacher must be able to answer the question as well. To avoid the consequences of innovative questions and answers, teacher may ask the question from the material, which is not allowed during the exam and the solution is available somewhere. If teacher does not keep the honesty then this method is as good as traditional exam as no innovation in the questions are expected and the evaluation is like cheating the students.

E. Open Source Exams

Yet another method, similar to open book exam is open source exam. In this kind of exams, students can use any material may or may not related to the subjects or even Internet. Students may solve the problems in groups as well. In such methods it is extremely important for the teacher to be competent enough to set the questions, whose answers are not directly available anywhere[12]. There is plenty of opportunity for the students to learn new things with all available content. If the teacher can set an actual innovative problem then students must learn many things from the exams. They will be able to apply the knowledge explored by them or by anyone else in the world to solve a specific problem. The beauty of such exam is that there can be multiple solutions possible for one problem and they may be acceptable as well. The biggest problem is the time require to conduct such exams. The fixed time limits given to traditional written exam may not be suitable for such exams. Teacher must decides the timing carefully so the problem can be answered fairly. The burden on the part of teacher increases in such exams, but the teaching learning process that take place is much more valuable than any burden that a teacher has to borrow. Well, open source or open book may not be possible in all the subjects. Some subjects are theoretical subjects and some are fundamental subjects in which, a teacher may not ask innovative problems as the fundamental knowledge is to be tested. In such type of subjects traditional exams are must. Innovations are applicable to the subjects which are application oriented or advanced research topics.

F. *Project Based Exam*

A proposed method that can be considered as one of the most effective method is project based evaluation. In such scheme one or more than one project is allocated to a group of students. Students knowing nothing about the subject, find the content related to same, may be using Internet or other literatures in consultation with the teacher. Students solves all the difficulties themselves and may ask for support of faculty if require. The final output of the project sets the evaluation criteria. Rubrics can be designed to evaluate such outcomes. In this method students have ample opportunity to learn as they start from the scratch. The major problem in this method is that the project definition. If a proper definition, which satisfy the subject learning requirement, is not designed then this method results in improper learning. Students may learn things out of the project but the learning may not be at par or exactly related to the subject. Moreover, teacher must spend ample time to explain the basics and the exact outcome of the project to the students so that they can execute the assignment properly. This method helps learning to students as well as teachers. As students start from scratch and not knowing anything about the implementation initially, lots of innovations are also possible. This method inculcates research attitude amongst the students.

III. A SURVEY CONDUCTED ON INNOVATIONS IN EVALUATION AND RESULTS

The exams are finally taken by students, so their opinion matters the most. To know the opinion of students, a survey was conducted on more than 500 students about various methods of exams and their effectiveness. The results are not surprising and are similar to what is discussed in the paper so far. The survey is carried out on the students of engineering, who are undergraduate, postgraduate and Ph. D. students. The discussion on various questions is as follows:

When it is asked to the students what exam method they like the most then the most common answer received was the project based learning. Fig 1. Shows the response of students about the method evaluation.

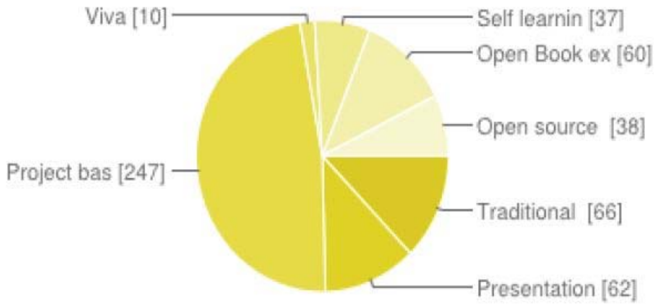


Fig 1. What kind of exams the students like the most?

Out of the 520 students taken the survey, around 47% (247 students) think that the project base exams are the best method for evaluation while only 10 students and 66 students are in favor of viva based and traditional exams respectively. Out of 76, total 23 students who favor viva or traditional exams are have got failure in exams at least once in their studies. 57 out of 247 students who favor the project based exams have got failure in exams. Total 98 students favors open book or open source exams out of which 29 have got failure in exams. The results shows that the students who favors traditional exams, has large number of students who have failed in the exams and may want only traditional exams so that they can pass it easily. However, around 25% students who are failed and favor the project base exams, think that the traditional exams do not judge their potential in a right way. Fig 2 is the opinion of students about the effectiveness of traditional exams. The question is that whether the traditional exams are proper way of evaluation.

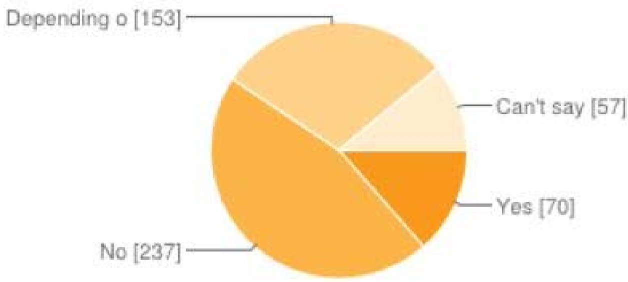
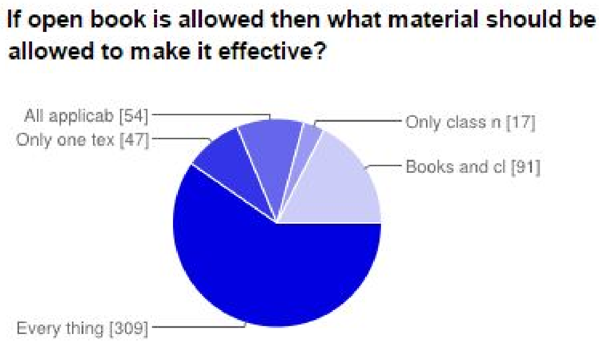


Fig 2. Effectiveness of Traditional Exams

When the question about the traditional exam is asked, 45% students out of 520 say that traditional exams are not a proper method of evaluation. Rather more than 40% also think that more than one method of evaluation can be combined. When it is asked that the project based method is the proper method of evaluation then 60% student agree that project based evaluation is proper method if applied in a proper way to the proper subject. Around 16% think that the success of project based learning depends on the nature of the subject.

If open book or open source exams are to be conducted then the opinion of 58% student is that the exam has to be open source and everything related to the subject must be allowed in the exam hall. If the exam is open book then it is as good as traditional exams if limited literature is allowed is view of 70% that can be seen in Fig 3.

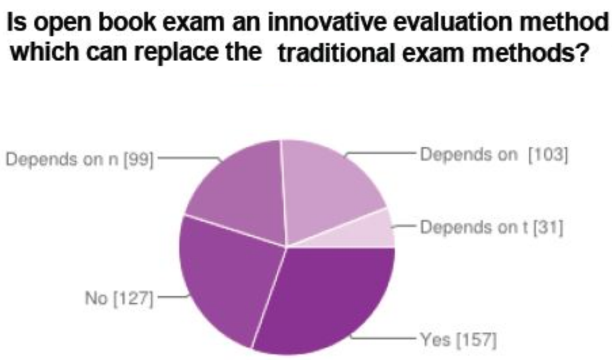


Every thing related to subject including Internet	309	58.7%
Only one text or reference book	47	8.9%
All applicable books	54	10.3%
Only class notes	17	3.2%
Books and class notes	91	17.3%

Fig 3. Literature/Material allowed for Open book/source exam.

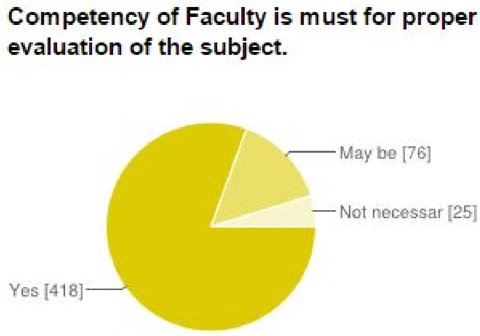
Moreover, only 30% students think that open book or open source exam is an innovative way of evaluation. Fig 4 shows the opinion of students about the effectiveness of open book/source exams.

In any method of evaluation the competency of teacher is must. If teacher does not devote the self then the evaluation method is not appropriate. 80% students feel that the competency of teacher is must for proper teaching and learning take place.



Yes	157	29.8%
No	127	24.1%
Depends on nature of subject	99	18.8%
Depends on nature of questions asked	103	19.6%
Depends on time allotted for exams	31	5.9%

Fig 4. Effectiveness of Openbook/ Opensource exams



Yes	418	79.5%
May be	76	14.4%
Not necessary	25	4.8%

Fig 5. Requirement of Competent Teacher

Moreover, 58% students feel that the exam should be conducted twice a semester at a predefined time. Maximum marks and passing marks of the exam should also change with the subject as per the view of 43% students. 57% students favor relative grading for the evaluation of the subject.

Conclusion

All the exam methods discussed have their own pros and cons. For modern education systems traditional exams may not work well. Project based exam can be considered as a future evaluation process. If properly conducted and evaluated, project based exams provides adequate opportunity to learn and explore the extremes in field of interest.

References

[1] Fui-Theng LEOW, Mai NEO, "Interactive Multimedia Learning: Innovating Classroom Education in a Malaysian University" The Turkish Online Journal of Educational Technology – April 2014, volume 13 issue 2, pp 99-110.

[2] Yahya, Y.; Nielsen, D.N.; Mukhtar, M., " Innovation in teaching and learning using service oriented approach", Electrical Engineering and Informatics (ICEEI), 2011, pp. 1 - 4, DOI: 10.1109/ICEEI.2011.6021663

[3] Shabnam Bidariana, soheila Bidarianb, Amirhosein Mohammad Davoudic, "A Model for application of ICT in the process of teaching and learning", Procedia - Social and Behavioral Sciences, Elesvier, 2011, Vol No. 29, pp. 1032–1041

[4] Oriah Akir , Tang Howe Engb, Senian Maliec, "Teaching and Learning Enhancement Through Outcome-Based Education Structure and Technology e-Learning Support" Procedia - Social and Behavioral Sciences, Elesvier, Volume 62, 24 October 2012, pp 87–92

[5] Vijayalakshmi, M.; Desai, P.D.; Joshi, G.H., " Outcome based education performance evaluation of capstone project using assessment rubrics and matrix", IEEE International Conference on MOOC Innovation and

Technology in Education (MITE), 2013, pp 6 - 10, DOI: 10.1109/MITE.2013.6756295

[6] Julia Bredtmanna, b, Carsten J. Credea, c, Sebastian Ottena, “Methods for evaluating educational programs: Does Writing Center Participation affect student achievement?”, Journal of Evaluation and Program Planning, Elesvier, February 2013, Vol 36 (1), Pages 115−123.

[7] Virginia Prendergast, Cindy Kleiman, Mary King, “The Bedside Oral Exam and the Barrow Oral Care Protocol: Translating evidence-based oral care into practice”, Intensive and Critical Care Nursing, Elesvier, October 2013, Vol. 25 (5), pp. 282−290.

[8] Naama Sabar, “Toward principled practice in evaluation: Learning from instructors' dilemmas in evaluating graduate students” Studies in Educational Evaluation, Elesvier, 2002, Vol. 28 (4), pp. 329-345.

[9] Kay Sambell, Liz McDowell, Sally Brown, “ “But is it fair?” : An exploratory study of student perceptions of the consequential validity of assessment”, Studies in Educational Evaluation, 1997, Vol No. 23 (4), pp. 349-371

[10] Richard Stiggings, Judy Alter, Jan Chappuis and Steve Chappuis, “Class Room Assessment for Student Learning – Doing It Right – Using It Well”, Assessment Training Institute.

[11] Dr Paul Maharg, “The Culture of Mnemosyne: Open Book Assessment and the Theory and Practice of Legal Education”, International Journal of The Legal Profession, May 2011.

[12] Dr Joy-Telu Hamilton-Ekeke, “Conceptual Framework Of Teachers’ Competence In Relation To Students’ Academic Achievement”, International Journal of Networks and Systems, Vol.2(3), 15-20, April 2013.

Teaching of Mathematics in Engineering by Discussing the Different Conceptual Ideas

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***Abstract*— Teaching of mathematics in engineering quite often becomes the mere mechanical process. Students of engineering branches lost their interest of mathematics due to the same. In the present work points are given to make the mathematics teaching interesting in engineering by discussing the different conceptual ideas of the topics. The benefits of the learning with the insight of conceptual ideas of mathematics are also derived and attempt is made to encourage mathematics faculties to think ahead and work in the described direction.**

Keywords—Conceptual Ideas, Green's Theorem, Cayley-Hamilton Theorem, Provoke thinking.

I. Introduction

Mathematics is one of the fundamental subject of Engineering. As, well, teaching and learning of the mathematical subjects are essential in various engineering disciplines. The mathematical subjects are offered everywhere in engineering institution but the various conceptual ideas behind the topics are rarely discussed. The process of teaching and learning mathematical topics remains only materialistic and that is the reason for the students to lose the interest in the topic easily. The discussion of the conceptual ideas are neither to talk about the proofs of the theorems, those proofs are often the manipulative in work nor the talk on historical development. The teaching without proper discussion of conceptual ideas lead to the misconception of the research. Students start believing that research is an outcome of accidental process not the outcome of extensive studies.

The discussion of the concept is the process of finding the different thought behind the idea and the derivation of the work. By discussing the conceptual ideas students get the insight of the topic. They understand the development of the subject. They come to know about that finding of the research are the learning and thinking process not the accidental thing. It makes session learning interesting and students remember it for the long time. The conceptual development learning encourage all to think about the ideas derived and utilization of the same can be possible even after a long time.

II. Examples to Explain the Procedure

Here, I would like to quote two examples to describe the conceptual teaching of Mathematics:

The 1st example is of the well-known Green's Theorem from the topic of vector calculus. The Green's theorem state that "the line integral around closed curve can be transformed to the double integral inside region of that closed curve". There are many alternate proofs are available in texts which prove the statement of Green's theorem by doing mathematical juggling. But important question behind the Green's theorem is how can it be realize physically? Was it a nightmare or Green's caught the idea accidentally?

Let me try to clarify it. Here it is important to note the point that we are not discussing history of the Green's theorem rather we would like to understand the conceptual development of the theorem. This is the result of deep learning process of George Green. He must not be interested to convert single integration into double integration at all. He thought of the process in the form of divergence theorem [1] and letter Green's theorem was derived by the work different mathematicians like Augustin Cauchy & Bernhard Riemann.

Physically the integral $\oint_c \vec{F}\, d\vec{r}$, where C is the closed curve thought as the microscopic circulation of the vector field $\vec{F}$ inside the closed curve C. See the figure below.

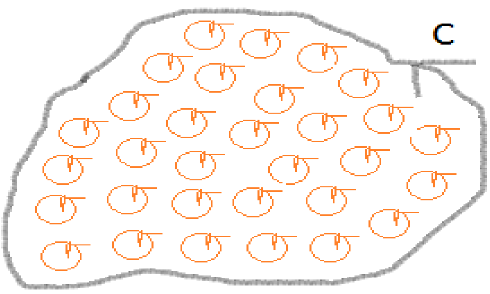

Fig.1 Microscopic Circulation inside the curve C

We could see in figure 1, the microscopic circulation as a bunch of small closed curves, where each curve represents the

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tendency for the vector field to circulate at that location (imagine that the small curves were really small, much smaller than pictured) [2].

By summing all these microscopic circulations inside the interior domain say D of the closed curve C transforms integral $\oint_c \vec{F}\, d\vec{r}$ into the double integrals of the microscopic circulation over D. i.e.,

$$\oint_c \vec{F}\, d\vec{r} = \iint_D \left(Microscopic\ Circulation\ of\ \vec{F}\right) dA$$

Now, the question is how to represent the microscopic circulation mathematically? Well, microscopic circulation in the xy-plane turns out to be the z-component of the curl (Right-hand thumb rule) [3].

$$\therefore Microscopic\ Circulation = \left(Curl\ \vec{F}\right)\cdot k = \frac{\partial F_2}{\partial x} - \frac{\partial F_1}{\partial y}$$

$$\therefore \oint_c \vec{F}\, d\vec{r} = \iint_D \left(\frac{\partial F_2}{\partial x} - \frac{\partial F_1}{\partial y}\right) dA$$

Which is the mathematical statement of the Green's theorem.

The 2nd example is again well known theorem of Caley & Hamilton. Generally, Mathematics Teacher simply state the Cayley Hamilton theorem as "Replacement of Eigen value λ in the characteristic equation by the matrix A go through as well" and all can verify it very easily. But the point is how Cayley & Hamilton derive it? Is that the part of accidental research? Or did they derive it by trial & error? I came to know about one procedure behind it. We know multiplication of 3 x 3 matrix with 3 x 1 matrix result into 3 x 1 matrix. If we keep multiplying the same matrix with resultant vector four times as an output we will have four vectors of the order 3 x 1. Now if we check these vectors are linearly dependent as they are more than the order of the original matrix [4]. So, we can express one vector as the linear combination of others and this linear combination exactly match with the characteristic equation. Let us understand this procedure with an illustration.

Let, $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$ be the real square matrix of order 3.

The characteristic equation for the matrix *A* is,

$\lambda^3 - 15\lambda^2 - 18\lambda = 0.$

Now, if we initialize the process of multiplication of matrix A with nonzero initial vector $e_1 = [1\ 0\ 0]^T$, we get

$$Ae_1 = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 4 \\ 7 \end{bmatrix}$$

Repeating the multiplication process, we get

$$A^2e_1 = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}\begin{bmatrix} 1 \\ 4 \\ 7 \end{bmatrix} = \begin{bmatrix} 30 \\ 66 \\ 102 \end{bmatrix},$$

$$A^3e_1 = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}\begin{bmatrix} 30 \\ 66 \\ 102 \end{bmatrix} = \begin{bmatrix} 468 \\ 1062 \\ 1656 \end{bmatrix}.$$

As a result we have set of four 3 x 1 vectors

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 \\ 4 \\ 7 \end{bmatrix}, \begin{bmatrix} 30 \\ 66 \\ 102 \end{bmatrix} \ \&\ \begin{bmatrix} 468 \\ 1062 \\ 1656 \end{bmatrix}.$$

Clearly, these vectors are linearly dependent vectors.

So, we can express one vector in the form of linear combination of other vectors. If we derive the linear combination then it is like,

$$\begin{bmatrix} 468 \\ 1062 \\ 1656 \end{bmatrix} = 15\begin{bmatrix} 30 \\ 66 \\ 102 \end{bmatrix} + 18\begin{bmatrix} 1 \\ 4 \\ 7 \end{bmatrix} + 0\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$$\Longrightarrow A^3e_1 = 15A^2e_1 + 18Ae_1 + 0e_1$$

$$\Longrightarrow A^3 = 15A^2 + 18A \Longrightarrow A^3 - 15A^2 - 18A = 0.$$

Which is exactly matching with the characteristic equation of the matrix A. The process remains true for any square matrix of order n and that is the general statement of the Cayley & Hamilton theorem.

III. Conclusion

By discussing the conceptual ideas in the way describe here encourage students to learn extensively. They clear their thoughts about research that research is not an accidental process. They find the process interesting. Even Teacher will be encouraged and can get the same benefits by doing the mentioned exercise. I accept the limitation of the work present here and expect mathematics teachers to work more in this direction. The study is thought provoking for all.

Acknowledgment

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References

[1] George Green, An Essay on the Application of Mathematical Analysis to the Theories of Electricity and Magnetism (Nottingham, England: T. Wheelhouse, 1828).

[2] http://mathinsight.org.

[3] Hughes-Hallettt, Gleason, MaCallum ET AL., Calculus Single and Multivariable, Wiley Publication.

[4] Lang, Serge (2002), *Algebra*, Graduate Texts in Mathematics 211 (Revised third ed.), New York: Springer-Verlag, ISBN 978-0-387-95385-4, MR 1878556.

Sensitizing Engineers

A Brief Study of the Role of Ethics in Engineering Education

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***Abstract*—This paper focuses on the essentiality of incorporating ethics as a course in engineering education. It claims that an amalgamation of ethical awareness and engineering skills can enable the future engineers to strengthen the relation between technology and society.**

***Keywords*—engineering; philosophy; ethics; society.**

I. Introduction

Ethical awareness is doubtlessly an essential requirement in engineers and this fact rarely evokes a disagreement. We tend to feel that being ethical is good, as it sounds good and makes us look good in the eyes of others, thereby, proving that we all want to fit into our individual notion of the 'good', which, at the same time, should coincide with the sense of morality sustained by our social climate. If that concept of good is challenged, our belief system, which is its rootage, is challenged as well. However, did we consider that the idea of goodness varies from person to person? In that case, some questions arise. If our beliefs are open to scrutiny and can afford to have exceptions, are they fundamental and absolute? Where do our ethics come from? Is it from religion or family? From culture or from nature? Answers to these questions, unlike those to empirical questions which can be concretely found if the resources are known to us, are hard to find. To define 'ethics', one may say, "it is the branch of study dealing with what is the proper course of action for [the hu]man" [1]. As contested earlier, the sense of propriety is bound to vary from person to person. Hence we can say that we all have our own set of ethics which is socially, geoographically, culturally, religiously and professionally conditioned. Students who have been oriented into the study of engineering require a sound sense of ethics to make professional decisions in future. In this age of artificial intelligence, where human beings are successful in creating computers as well as computer softwares capable of intelligent behaviour, it is equally essential that they are capable of making appropriate professional decisions as engineering has a direct relation to the society's welfare. In this enterprise a mandatory requirement is the individual's ability to "think". Psychologist B. F. Skinner famously said: "The real problem is not whether machines think but whether men do." The concern raised by Skinner is all the more applicable in the case of the present generation of students who are habituated to decide upon things instantly, taking less efforts in reasoning out what are the other available options. Ethics provide students with a vantage point from where they can have an objective approach towards any problem, which is also the first step of problem-solving. "...the essential prerequisite to solving any problem is to define exactly what the problem is, and the engineering approach truly emphasizes this point. The need to propose possible solutions and evaluate them requires the formulation of a 'thought' model or analogy based on the particular circumstances and a logical process of evaluation. Again, the fact that there is no unique solution to an engineering problem, but only a compromise solution chosen from a number of possible solutions, is another essential concept in solving real-world problems and leads directly to the need for decision making processes" [2]. In this quote from Professor Douglas Lewin's article named "Engineering Philosophy –The Third Culture?" the author tries to exonerate engineering from the constricted definition which delimits it to be a profession that aims at merely designing and manufacturing artifacts. He demands for the recognition of an engineering philosophy that shall broaden the purview of the profession and uphold its creativity in problem-solving within a perplexed environment. While emphasizing the necessity of an engineering philosophy, Lewis opines that doing so shall liberate engineering education through a confluence of the arts and sciences.

Engineering philosophy, which concerns itself with the philosophical issues that are applicable to engineering, also includes ethical concerns. Hence prediction related to an artifact is not only about its proper functioning but also regarding its social usability and value. However, ethics is better understood if one learns about the different philosophical approaches towards decision-making that has been the prerogative of philosophers so far. The realisation that our point of view is not the one and only way to interpret something, makes us respect other's perceptions.

II. Ethics as a Branch of Philosophy

Unfortunately, an average human mind grossly misconstrues the word "philosophy". There is a popular tendency to correlate it with "something" that is otherworldly,impractical if not unexplanable. That philosophy shares an integrated relationship with each and every branch of knowledge thus gets a clean miss. The following words of Philosopher Simon Blackburn might help us to identify the practicality of philosophy as a body of knowledge as well as the necessity of engineering education to collaborate with it. "I would prefer to introduce myself as doing conceptual engineering. For just as the engineer studies the structure of material things, so the philosopher studies the structure of thought. Understanding the structure involves seeing how parts function and how they interconnect. It means knowing what would happen for better or worse if changes were made. This is what we aim at when we investigate the structures that shape our view of the world. Our concepts or ideas form the mental housing in which we live. We may end up proud of the structures we have built. Or we may believe that they need dismantling and starting afresh. But first, we have to know what they are" [3]. To identify the frameworks which shape our worldview, primarily we need to understand that our beliefs are not "natural" but socio-cultural constructs. One's notion of right and wrong is, therefore, not bound to coincide with that of someone else. As Alain De Botton says:"The philosopher does not only help us to conceive that others may be wrong, he offers us a simple method by which we can ourselves determine what is right. Few philosophers have had a more minimal sense of what is needed to begin a thinking life" [4]. Philosophy thus turns out to be the passage to arrive on ethical ideas through a series of logical reasoning. In the following paragraph, we shall have a brief look at some of the common philosophical ideas that have been popular since ages.

Jeremy Bentham and John Stuart Mill introduced the concept of utilitarianism which claims that, if an action benefits a large number of people, the action is right, turfing out the number of people who suffered as they are less in number. Morality in this case is completely consequential. On the other hand, German philosopher Immanuel Kant propounded the philosophy that an action is morally worthy only if the doer has a noble intention. In Kantian philosophy of morality, a correct action can be morally worthless if one has an unreasonable purpose behind it. Classical philosopher Aristotle opines that justice is giving people what they deserve. This theory in turn, calls forth the question: who decides what a person deserves and how? On the other hand, contemporary philosopher John Rawls thinks that justice is possible only if our basic liberties are decided by a citizenry which is temporarily oblivious of its social, ethnic, cultural and economic identity since, under such circumstances, there would be lesser chances of biasness. These were just a few of the various other philosophical approaches towards morality that have been proposed by eminent philosophers. A philosophical approach towards any body of knowledge initiates the functioning of the inquisitive faculty of the mind which does not accept opinions as facts without reason and justification. Philosophy increases our objectivity towards the subject under concern and therefore gives us a number of slants to perceive the same situation. However, the ethics which we chose for ourselves after reading the subject through different lenses is a matter of individual subjectivity.

Subsequently, ethics can be considered as the more practical side of philosophy. "It can in turn be divided into the general study of goodness, the general study of right action, applied ethics, meta-ethics, moral psychology, and the metaphysics of moral responsibility" [5]. Applied ethics deserves a special mention as it reveals the underlying philosophical ideas behind our day-to-day phenomena at work in particular and in our surroundings in general.

III. Ethics and Engineering Education

The common or rather primitive view of the pattern in which engineers usually work, is the "received view" according to which, engineers are mere participants in enormous organizations where decision-making is the privilege of managers, thus leaving the engineer with minimum authority in taking decisions. "Managers choose what to do, divide work into small jobs, and assign each job to one engineer or small group. Communication between engineers is kept to a minimum to assure management control. An engineer may need permission from his boss even to discuss a project with an engineer in another department or working group. Engineers identify options, test them, and report the results to managers. Managers combine these reports with business information they alone have. Managers decide. Engineers merely advise" [6]. Under such circumstances, the Engineer needs to decide, say, when to blow the whistle or whether to blow it at all. And to do so, the engineer needs to consider her/his area of work as a rational undertaking in order to locate the ethically objectionable issues within it. Taking the right decision under such circumstances becomes crucial because the consequence of such decision-making might have a panoptic effect on the organization as well as on the society. A brief discussion on the *Challenger* disaster might explain the significance of ethical decision–making in the engineering profession. It shall also delineate the horrid consequence that can follow when ethics go wrong.

The space shuttle *Challenger* disaster has, by now, become a classic case study to discuss matters such as whistleblowing, organizational work culture and social security concerns. It also exposes the threats of erroneous organizational practices such as 'groupthink' and 'go fever' and shows the dire consequences of overruling the engineer's advice while making technological decisions. The engineer Roger Boisjoly, who had advised against launching the shuttle in the cold weather, was ignored by the Morton-Thiokol management. This overruling makes a case of unethical decision-making on the part of the management body. In his essay "Technical Decisions: Time to Rethink the Engineer's Responsibility" Michael Davis expresses the views of Rosalind Williams, who is a Historian of Technology at MIT, on the *Challenger* Disaster. According to her observations, "…the Challenger disaster is not a case in which mere managers overruled engineers. Those doing the overruling, three of Thiokol's vice-presidents, all had degrees in engineering. Mason had a bachelor's in aeronautical engineering; Lund, a bachelor's in mechanical engineering. Though Kilminster's bachelors was in math, not engineering, he had a masters in mechanical engineering. The *Challenger* is a case of engineers with management responsibility ignoring the advice of other engineers, their technical staff, not of MBAs run amok." One of the other important reasons behind such nonchalance towards engineers is the pressure that customer-oriented companies create on their management bodies, which, in turn transfer the same to the engineers working under them, thereby curbing the engineer's authority in decision-making, unlike the work culture of engineering-oriented companies where managers and engineers do reject customer requests which, if kept, might challenge the company's ethics.

Incidentally, just a year before the *Challenger* disaster, the Accreditation Board for Engineering and Technology (ABET) in the United States decided that an understanding of the ethical features of engineering should be mandatory for all students pursuing engineering programs. The interpolation of ethical awareness within engineering programs in ABET might have initially appeared to be a fad as applied ethics, especially in the field of medicine, was gathering a lot of attention during the 1970s. However, the coincidental occurrence of the challenger disaster just a year after this modification by ABET established the essentiality of ethical standards in the engineering domain. "The ABET 2000 requirements are more specific, requiring that graduates of engineering programs have an understanding of the impact of engineering in a global and societal context, as well as an understanding of contemporary issues related to engineering. ABET 2000 also requires that students have a "major design experience" that includes ethical factors in addition to economic, environmental, social and political factors" [7].It is of the utmost importance for the engineer to know that her/his work does not stand in isolation for its own sake. Therefore, while approaching any engineering project the engineer has to keep in mind the effect as well as the utility of the project on the society. Here I would like to discuss another kind of ethical awareness that has become an essential requirement of almost all corporate houses, namely: Corporate Social Responsibility (CSR).

Today, the rapid advancement in business economy can definitely be attributed to the extreme technological sophistication. We all are aware of the extent to which technology is being used to meet company targets and raise their global standards. Under such circumstances, it becomes essential that companies not only enjoy the yields of their business profits but also stand responsible for the social and economic effects their activities have on the society. A corporation's social responsibility shows the way/s in which it pays back to the society. This is relevant to engineering students as recruitments of engineers in customer-oriented companies have increased in recent times. So, even if engineering students go for startups, which is highly in trend right now, an awareness of CSR would help them stand out in the crowd.

IV. Ethics as a Tool in Enhancing Engineering Education

Teaching ethics in a classroom filled with engineering students can be a tough challenge, as 'ethics' has an apparent simplicity which is actually deceptive. It appears to be something that students feel that they already know. Hence, the facilitator needs to treat ethics as a tool to enhance the student's overall teaching-learning experience. They need to realise that whereas different disciplines make us see and interpret the world through different lenses, philosophy in general and ethics in particular brings those very lenses under examination. Briefing them on some of the classical philosophical frameworks which examine concepts like truth, justice, liberty and so on, broadens their outlook towards life. Society grooms us to accept long-established norms unquestioningly. It is philosophy that questions the base of those norms and compels us to doubt their authority. Socrates' method of examining common sense could be one of the ways of doing so. Socrates wondered whether the notion of 'popularity' made any sense as we all commit the mistake of linking popularity with correctness.

Interpreting twenty-first-century social, cultural and economic phenomena in terms of classical philosophies can be a fascinating activity in class. For example, a Kantian analysis of shopping in malls or a libertarian analysis of a cricket match or a utilitarian analysis of whistleblowing would increase the inquisitiveness of the students and deepen their observations.

While teaching this course to higher semester engineering students, it is often noticed that some students cannot relate to general ethical concerns or are nonchalant towards them. The reason behind this could be the fact that they either cannot locate the problem, or else they do not know how to generate an opinion. Such students can be asked to comment on ethically questionable issues from their day to day practices such as offline and online gaming, advertisements, use of expensive gadgets like smart phones, restrictions as well as legal enforcement of morality. Consequently, students themselves come up with the various ethical issues they face in something as commonplace as gaming. Exposure to violence, addiction, encouraging restlessness are some of the unethical by-products of the gaming industry which were pointed out by the third semester civil engineering students. When asked to opine on such relevant issues, students share their points of view with each other and the entire class benefits from it. These discussions help the students to break the ice as most of them, to their own surprise, come up with an opinion upon the issues.

When students are asked to present on practical issues under applied ethics, they use the different theoretical frameworks of moral philosophy and try to analyse the problem in their own way. For example, in the previous semester, fourth semseter electrical engineering students were supposed to present on various kinds of discrimination and their effects. The group comprised of seven members. The class had expected a conventional, formal presentation. However, the group came up with a beautiful skit which acted out the vices of discrimination. When some of the students in the audience made fun of the unconventional presentation through boos and catcalls, the performing group intelligently contextualised that behaviour to their presentation, calling it the mob-culture, which criticises anything that is different, thereby escalating the upshots of discrimination on the basis of race, caste or ethnicity.

Hence we can say that making the students realise the presence of ethical issues in the current affairs or even in their daily practices creates a greater awareness among them. Through the presentations and theatrical performances students have a dynamic teaching-learning experience in the classroom.

V. CONCLUSION

As far as the requirement of teaching ethics to engineering students is concerned, one might often find it insignificant, as an ethical malfunction like the *Challenger* disaster occurs rarely. Moreover, any technological enterprise, even if it is as commonplace as a domestic flight, carries a risk of going astray. Which means, that if we enjoy the success of technology, we must also be ready to bear the brunt of its failure. When technological errors are inadvertent in nature, engineers have least culpability as no one can be actually held responsible for it. But when technological errors are a result of unethical decisions on the part of engineers, they are the ones to be held responsible for the loss. We should realise that technological disasters damage the society's faith in technology as well. Along with their technological capabilities, engineers are mandatorily required to culture their ethical awareness to retain the society's reliance on science and technology. Ethical awareness makes the engineers conscious of their roles outside their office and they realise the power they have in transforming lives through innovation and design. In this article, we have tried to show the ways in which ethics as a course helps in the overall development of our engineering students and how it can act as a tool to sensitise them towards their obligations towards the society. In so doing, we have argued in favour of a reconciliation between the two historical belligerents: humanities and science. Hence we found Theo Jansen's words, that, "The walls between art and engineering exist only in our minds" extremely pertinent.

REFERENCES

[1] J. Landauer and J.Rowlands(n.d.),"What is ethics?"[Online]. Importance of Philosophy, Available: www.importanceofphilosophy.com May 16, 2015 [date accessed].

[2] D. Lewin, "Engineering philosophy—the third culture?" London: Royal Society for the Encouragement of Arts, Manufactures and Commerce, vol. 129.5302, 1981, pp. 653-666, p. 661.

[3] S. Blackburn, Think: A Compelling Introduction to Philosophy, London: Oxford University Press, 1999 (n.p.).

[4] A. D. Botton, ,The Consolations of Philosophy, New York: Vintage, 2001 (n. p.).

[5] R. Audi, The Cambridge Dictionary of Philosophy, 2nd ed., Cambridge: Cambridge University Press, 1999, p. 284.

[6] M. Davis, "Technical decisions: time to rethink the engineer's responsibilities?" Virginia: Philosophy Documentation Center, 1992, pp. 41-55, p. 42.

[7] R.G. Frey and C.H. Wellman, A Companion to Applied Ethics, Oxford: Blackwell,2003,p.621.