INTERNATIONAL STUDENTS, PLAGIARISM AND ACADEMIC WRITING: CAN SCIENCE AND ENGINEERING EDUCATORS MAKE A DIFFERENCE?

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ABSTRACT
The need for good scientific academic writing has been found to be of importance in science and engineering education. A literature review and analysis has been carried out on the good scientific academic writing. The paper critically looks at the problem of plagiarism and how it affects the performance of students. It looks at the reasons why students plagiarise. It analyses the methods that could be used to deal with the problem of plagiarism. The paper looks at the steps that can be taken to evaluate whether methods used to stop plagiarism have been effective.

Keywords: Scientific Academic Writing, Plagiarism, International Students, Science and Engineering students

RESUME
La nécessité d'une bonne rédaction scientifique a été jugée d'importance en sciences et dans l'éducation en sciences de l'ingénieur. Une revue de la littérature sur la bonne redaction scientifique a été réalisée. Cet article jette un regard critique sur le problème de plagiat et son impact sur la performance des étudiants. Il examine les raisons pour lesquelles les étudiants plagient et analyse les méthodes qui pourraient être utilisées pour y pallier. L'article aborde alors les mesures qui peuvent être prises pour évaluer l’efficacité des méthodes utilisées pour mettre fin au plagiat.

Mots-clés: Rédaction scientifique, plagiat, étudiants internationaux, sciences et étudiants ingénieurs.

1.0 INTRODUCTION
As the world globalises and becomes more interconnected, the flux of international students has also increased. For example, in 2005 at Lund University in Sweden, about 1000 students went abroad to study and approximately 1700 international students came to acquire higher education at Lund University (Svensson, 2016).
Like all new students, they carry or bring with them a diversity of ideas, assumptions and experiences. Yet, literature provides a range of mounting evidence that International Students (IS) are usually challenged on issues that domestic students are not. IS might experience emotional problems of living in a foreign country away from family and friends. They may even feel unsettled, anxious or depressed and problems that they had before leaving home possibly will also surface in the new environment (Turner and Spencer, 2006). They can also have socio-cultural shocks arising from discrepancies between home learning and host learning cultures (Biggs, 2003; Schneider, 2006) or even problems of gender equality, informality and relaxation, especially if they come from traditional societies. Moreover, they may also face language problems in understanding oral instructions, announcements, completing reading assignments, answering essay questions and understanding the meaning of key words on tests (Turner and Spencer, 2006).

Among the many existing challenges and obstacles international students face, this paper concentrates on two critical issues: genre academic writing and plagiarism. Two reasons justify this prioritisation: first, plagiarism, if not properly addressed can have serious consequences to international students not only during their academic life, but also in their professional careers. Plagiarism in higher education, not only weakens the academic standard by promoting surface learning, but it also negates International Property (IP) rights and the efforts of other students who do not plagiarise (Juwah et al., 2003). In a more competitive global economy, rules and penalties regarding plagiarism and IP are therefore becoming stricter and harsher. Secondly, the paper considers that plagiarism is a manifestation of a deeper problem linked to the lack of sufficient capacities and skills that IS have in developing sound academic writing practices (Biggs, 2003). And it is here, where university lecturers and tutors equipped with adequate pedagogical approaches and teaching-learning techniques can make a difference as these are areas directly linked to recurrent academic deliverable products such as papers and reports.

This paper is divided into three parts. The first part starts by identifying critical issues related to international students, academic writing and plagiarism. The section reflects the search done on the worldwide web on available literature that commonly discusses these three subjects. It is then followed by a discussion on those issues that lecturers can actually influence or not. The analysis is based on: a) personal experience as an international graduate student who lived through both as an international student and lecturer at a foreign university; b) anecdotal interviews done with some staff members a university, and c) a review of relevant content and literature. Finally, suggestions, and more practically, strategies and methodologies that lecturers can adopt to stimulate better academic
writing among international students which can, therefore, help to overcome plagiarism are identified. This includes methods of assessing the outcomes of the suggested strategies.

2.0 GENRE ACADEMIC WRITING AND PLAGIARISM
In recent years, International Students are increasingly facing learning obstacles given their insufficient knowledge and managerial skills in genre academic writing. Their difficulties go from practicing, and reflecting upon the conventions of written texts (in this particular case in the English language) which include critical reading (evaluating arguments); micro-level argumentation (paragraphing); to making decisions about style; nature of research writing; using and citing the work of other authors in their own writings (Biggs, 2003).

As the instruction and dominant language used in western universities and in most scientific and engineering writing is English (Kushner, 1997), its appropriate academic use is becoming a recurrent topic that needs to be confronted by students and their lecturers (Lax, 2002). Genre academic writing training in English is therefore fundamental for non-English speaking but also to English speaking IS accepted for tertiary education in universities.

Carroll (2002) suggests that: ‘although IS may have been successful in systems that required them to locate and reproduce answers, many have never attempted a piece of independent writing in any language, let alone an unfamiliar one such as English’. IS also have problems with accuracy of the language used, its fluency, cohesion and organisation. IS usually face limitations in preparing academic papers and avoiding the use of personal reference, colloquialisms, jargon, sexist language, stereotyping and ethnic bias (Anderson and Poole, 2001).

These academic writing capacities and skills are at the core of other critical issues like plagiarism that are becoming an increasing problem for both domestic and international students. Plagiarism has also become a main source of suspension at universities. For example, six students from Lund University were suspended for four months after they forged the results of a research conducted in collaboration with IKEA Company (Samuelsson, 2006).

2.1 What is plagiarism?
Plagiarism is using another writer’s words or unique ideas as if they were your own. It happens when you put those words, phrases or ideas into your research paper without indicating that they did not come from you. The professor believes those are your own words or ideas, because you have not stated that they came from someone else (Badke, 2009). To copy and claim others’ work as your own without acknowledgement is therefore plagiarism (Phillips and Pugh, 1997).
Wilson (2002) defines four stages of plagiarism: repetition, patching, plagiphrasing and conventional academic writing. In spite of the many definitions and stages of plagiarism, all include the common idea that text or other intellectual property are claimed as their own whereas it has been developed or invented by another person.

Two key factors however, must be distinguished in determining response to plagiarism:
(i) The student’s intent to cheat.
(ii) The extent of the plagiarism an individual student has committed.

As definition of plagiarism and views on what constitutes minor and extreme examples vary widely, it is not surprising that there is enormous confusion among students on this issue. And if they do not know what it is, how can they avoid it? When have they crossed the permissible line? Therefore, lecturers must be extremely clear on what plagiarism is, why it has to be avoided and probably more important, how can it be overcome.

2.2 Why do International Students plagiarise?
Plagiarism is becoming an increasing problem for both domestic and international students. According to a recent survey performed in Sweden in 2000 by the Knowledge Foundation (Urkund, 2006), 37% of the lecturers had experience of students plagiarizing. But 42% of the lecturers did not think they had sufficient knowledge to deal with the problem.

Yet, language problems and different cultural and educational backgrounds may explain why IS are considered to be more susceptible to plagiarism. IS face linguistic problems and cultural difference when moving to a foreign university. IS are usually non-native speakers of the language used in the host country, and use English as their second or third language. As a consequence, they may have a limited vocabulary, they may process the information slower, and they may find it difficult to rephrase the arguments of others with their own words.

Moreover, many IS do not know how to cite references from academic papers, journals and books they read and are not aware of the existence of reference systems. Many are not aware that an author’s idea, even if stated in other words, needs to be acknowledged (Phillips and Pugh, 1997). In that context, plagiarism may not be intended but rather a consequence of poor language skills and also lack of knowledge on how to reference.

IS coming from different educational and cultural backgrounds may plagiarise because they do not fully understand why plagiarism is considered as
misconduct. In their cultures, individual ownership of ideas may not be the norm and individualism may be considered as impolite and arrogant, whereas, on the other hand, one shows great respect to and honour an author/a teacher by quoting them word for word (Juwah et al; 2003). Memorisation and verbatim quoting may also be rewarded as a way to help deepening and consolidating learning.

Knowledge in the public domain, such as internet, is also considered as common knowledge in some Asian cultures, which leads to free copying of texts and ideas without any sense of misconduct (Juwah et al; 2003).

IS may also have problems identifying authors and their institutional affiliation; to determine whether the material is from an academic website or on a site that is known and from a reliable organisation. They may not take into consideration the need to identify whether the material is part of a series as in academic journals or whether the publishers are a scholarly or academic organisation, and also the date when the material was posted or updated on the web to ascertain how current it is.

The above mentioned are related to student problems but the surrounding is also an important element to understand the phenomena. Students at the university are not always encouraged to improve their skills to identify if the information has links to other information sources and whether citations to work of others are appropriately referenced.

What is the role of teaching in solving this problem? Many academic institutions in the world provide help especially geared towards IS. In the USA for example, these are typically termed Academic advisors (Turner and Spencer, 2006). Academic advisors can be helpful not only helping IS with practical arrangements but also with their learning experiences. But, the responsibility of assisting students in the teaching situation falls at the end of the day upon the teaching staff. The problem is that advising of IS can require expertise that some faculty members may have not had the opportunity to develop (Turner and Spencer, 2006). In the case of language barriers, it has been claimed that it is generally not considered the role of the subject teacher to assist students with their language. However, they should be concerned because “language and learning interact deeply” (Biggs, 2003). What, therefore, can be done to encourage and train?

3.0 METHODS TO DEAL WITH THE PROBLEM
It is not very clear, what is the best method to deal with plagiarism. Given the implications it has for academic and professional life, lecturers and international students should try to establish and agree clear rules and penalties regarding
plagiarism. Lecturers should have the necessary tools to detect it but also invest the necessary time explaining to IS the consequences of plagiarism.

3.1 Rules and Penalties
A simple method to reduce plagiarism may consist in clearly defining the rules of citation to the IS (Biggs, 2003). The teacher must explain in detail what plagiarism is and why it is not acceptable. At that stage, it is important not to imply that the host educational system is correct while the previous reference of the IS is wrong or inferior.

In practice, a special session on plagiarism may be introduced at the beginning of any course for IS. Time should be allowed for the teacher and the IS to discuss on the teacher’s expectations in relation to plagiarism. Moreover, the teacher instructions may be backed up with relevant concrete examples. Finally, there should be a way to assess that the plagiarism concept has been understood correctly.

Even, if clear rules of plagiarism are made accessible to IS, it may not be sufficient to prevent intended plagiarism. That is why penalties may also have to be implemented and used by universities at certain stages and probably as a last resort (Figure 1). In this sense, one should be able as a teacher to detect and punish students caught breaking expectations. Of course the students and their case must be referred to the appropriate senior level within the academic structure to be dealt with on a case by case basis and according to the laws that rule the teaching-student academic relation.

<table>
<thead>
<tr>
<th>Student intent to plagiarism</th>
<th>Entirely Deliberate</th>
<th>Unacceptable, even if minor. However, focus on education rather than punishment</th>
<th>This is a serious and inexcusable breach. Penalise quickly and appropriately</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Entirely Accidental</td>
<td>Don’t ignore. Focus on re-educating and on explaining expectations</td>
<td>Likely a significant misunderstanding. Renew education on expectations</td>
</tr>
</tbody>
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Figure 1: Plagiarism Intent-Extent-Response Graph (Devlin, [2004])
3.2 **Encouragement and training**

In spite of the fairness and probably impartiality of the abovementioned methods, the fact is that instead of being encouraged, confronted and trained and prepared to overcome their flawed practices in genre academic writing, IS are recurrently penalized with low grades and marks. This is done without any major thorough review together with their lecturers or their peers of the mistakes and inaccuracies committed, including those that can be categorised as plagiarism (based on anecdotal interviews with some members of staff at a Swedish university).

Individual tutoring and academic writing training may therefore help to overcome some common mistakes committed by IS: having conclusions that are repetitive, do not synthesise the key points in such a way to show the mastery of the subject. Ideas are not understandable and supported by details and examples. Thus, the need to have a clear organisational plan with sections having logical sequences should be sufficiently discussed with IS as well as the consistence of style and spellings and hyphenation, and the need to avoid redundant words, vague phrases, and awkward sounding sentences.

Many IS confronted with tasks that demand good writing skills are not sufficiently prepared and often unaware of the range of electronic tools to aid writers. These include thesaurus; online dictionaries, grammar checkers, style analysers, bibliographic software to organise and create bibliographies. A thesaurus, whether in book or electronic form, is without question a vital tool for writers. Proper use of words and smooth rhythm of the prose are essential for academic writing. Inconsistencies between English and American spellings are easily detected with a spelling checker. Writers should be consistent in using the various versions of English.

According to the literature review, interviews done and personal experiences, it is suggested that IS should be encouraged to participate in peer reviewing the preliminary draft papers from other students so that they learn from each other. However, lecturers should have in mind that IS from certain countries study in environments where competition is the reference and the key to success. Such students may then find it extremely difficult to participate into collaborative learning activities. Although, the reverse is also true: competition may be experienced as distasteful and frightening to them (Turner and Spencer, 2006).

Working in writing laboratories could also be encouraged. Yet some IS may never have experience in laboratory work or problem solving, but instead they express a preference for theoretical work. This originates from the values that they have been taught and in the content of their education. Consequently, many
students will be resistant to learn by technical work or manual skills that they consider below their ability (Turner and Spencer, 2006).

The use of mock paper and exams as a form of training before real papers and exams are handed in also enables the teacher to identify weaknesses in genre academic writing, but also it can assist in decreasing the levels of anxiety that IS can have. Caroll (2005) gives an excellent example on strategies for developing students’ writing with regards to the expectations that lecturers have of what is good answering in reports.

The students could learn how to use the writing tools using the Problem Based Learning approach (Biggs, 2003). They should be encouraged to write and hand in work short pieces of work for the lecturer to read through and give feedback on writing issues. The use of templates explaining in detail what each section should contain, how it should be prepared and presented (Roselund, 1994). This has proven invaluable in many cases.

Training for the organisation of the written material is, therefore, an important subject to IS. The need to structure texts with an introduction, the main body, and conclusions becomes critical. But very seldom, methodological discussions take place about how the introduction of a text needs to create a research space (CARS) (Swales and Feak, 2006). Or that the main body of the text should contain a critical analysis of the subject matter and then the section on conclusions should clearly sum up the study and state the major findings and recommendations.

Personalised tutoring is also an important tool for a dialogue as it can help to identify key problems that IS are facing while writing their academic reports. In this point, it is important to signal that special training of the tutors is also required. Tutors are not born to be tutors and special training courses in understanding the need of IS could also be useful.

4.0 HOW TO EVALUATE

These are the general skills that lecturers want students to have and include the following:

One can use a self assessment questionnaire that assesses the students about both attitudes towards writing. The student should be able to tell which areas of writing he or she has problems with and which areas are working well.

Periodic assessments between students and tutors using Structured Observed Learning Outcome (SOLO) levels are also recommended (Biggs, 2003).
The lecturer should go through the summary of the student’s current research; a descriptive and informative abstract of an article related to the student’s research or the beginning segment of a current writing task, and later a longer segment from a current writing task to see whether there has been improvement in writing.

One can also use an English Language Specialist for evaluation after the student has gained more confidence and is able to write longer pieces of work. Lecturers should also be more aware of methods that are available to detect plagiarism. Simple checks can be performed by manual checking the course book/manual or by using search engine for specific sentences/word combination in order to detect for unacknowledged quotations. Tools to specifically detect plagiarism have also been designed all around the word. This includes Turnitin UK (Student Learning and Centre English Language Teaching Unit, 2006), Urkund (2006), InfoTrac, EBSCOhost (Marywood University, 2012), Plagiserve.com, WcopyFind, Plagiarism Finder, Glatt, Essay Verification Engine (EVE2), Copy Catch Gold, MyDropBox.com, Moss, JISC Plagiarism Advisory Service, authenticate (Juwah, 2005)

5.0 FINAL REFLECTIONS
As shown, plagiarism is becoming an increasing higher educational problem in Sweden both for international and local students. It may be more critical for IS, given a variety of factors that are linked to their linguistic, cultural and educational backgrounds. Plagiarism does not only affect the academic life of IS but also their professional careers.

The problem, however, needs to be understood in a broader teaching-learning context. To overcome the problem, it requires the creation of an environment where lecturers and tutors not only discourages plagiarism but encourage the strengthening of academic writing capacities, techniques and skills. Penalties and sanctions are required but should be used as a last resort. In this sense, the authors of this report favour using preventive methods that function as incentives to achieve better genre academic writing.

Academic writing is, therefore, an important part of a learning process and the capacity of a student to master a subject. Horizontal exchanges with peers, individual tutoring and guidance can achieve better results than strict top-down vertical learning teaching. In this sense, it also relates to the capacities of lecturers of engaging students in deep learning approaches instead of superficial ones.
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THE EFFECTIVENESS OF NANO TECHNOLOGY EDUCATION FOR ADVANCEMENT OF ENGINEERING EDUCATION

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ABSTRACT
Although information, communication and technology in engineering education are considered as knowledge of the present era, nanotechnology in engineering is being regarded worldwide as the technology of the 21st century, which has unique phenomena and high properties that will be very important for engineering advancement. The revolution of nanotechnology due to physical, chemical, electrical, mechanical, magnetic, optical and other super characteristics, can be said to divide the world into advanced countries and developing.

To effectuate positive development in engineering education, society and humanity development, introduction of nanotechnology in engineering education is now one of the domestic and international challenges needing attention in order to solve the problems facing African societies, while simultaneously making safer life and better future for Africans.

In this respect, researchers have pointed to the importance of integrating disparate nanotechnology concepts into curricula matrices and teaching activities through all engineering educational stages to encourage learners to achieve and think towards advanced science facing the educational lack in this area internationally. This affirms that nanotechnology concepts need to be treated academically in order to attain contemporary educational objectives. This paper is an attempt to discover modern concepts in the curriculum and the teaching of nanotechnology that will be effective for advancement of engineering education in African countries.

Key words: nanotechnology, engineering education, curriculum, teaching, advanced science.

RESUME
Bien que l'information, la communication et la technologie dans l’éducation en sciences de l’ingénieur soient considérées comme des connaissances de l’ère actuelle, la nanotechnologie dans l’ingénierie est considérée dans le monde entier comme la technologie du 21ème siècle, qui a des phénomènes uniques et des propriétés élevées qui seront très importantes pour les avancées en sciences de l’ingénieur. La révolution de la nanotechnologie, en raison des caractéristiques physique, chimique, électrique, mécanique, magnétique, optique et bien d'autres
super-caractéristiques, tend à diviser le monde en pays avancés et pays en voie de développement.

Pour réaliser un développement positif dans l'enseignement de l'ingénierie, la société et le développement de l'humanité, l'introduction de la nanotechnologie dans la formation des ingénieurs est aujourd'hui l'un des défis nationaux et internationaux nécessitant une attention particulière en vue de résoudre les problèmes auxquels sont confrontées les sociétés africaines, en favorisant simultanément une vie plus sécuritaire et un avenir meilleur pour les Africains. À cet égard, les chercheurs ont souligné l'importance d'intégrer les concepts disparates de la nanotechnologie au cœur des programmes de formation et des activités d'enseignement à tous les stades de l'éducation en sciences de l'ingénierie, ce afin d'encourager les apprenants à atteindre et à penser les sciences avancées, face au déficit d'éducation dans ce domaine à l'échelle internationale. Cela confirme que les concepts de la nanotechnologie doivent être traités au plan académique en vue d'atteindre les objectifs contemporains de l'éducation. Cet article est une tentative de découverte des concepts modernes dans les programmes et l'enseignement de la nanotechnologie qui s'avèrent efficaces pour les progrès de l'éducation en sciences de l'ingénieur dans les pays africains.

**Mots clés:** nanotechnologie, éducation en sciences de l'ingénieur, programmes de formation, enseignement, sciences avancées.

1.0 **INTRODUCTION**

Nanotechnologie est créée comme un concept contemporain basé sur la miniaturisation des particules et grains d'atomes pour devenir aussi petits possible avec plus de caractéristiques super. Cela a des implications pour de nombreux domaines. Bien que la nanotechnologie englobe différentes sciences, il peut finir par inclure des caractéristiques plus élevées et des processus.

In this regard, developed countries have called to organise and manage nanotechnology practices for engineering education advancement and humanity development. Ernst (2009) and Davies (2005) suggested that the nanoscale progress is critical for national security, prosperity of the economy, and enhancement of the quality of life. Engineering education is one of the most effective systems to change peoples' behaviours, teaching them how to live and think towards the intending future in societies. In this respect, there is a need to incorporate nanotechnology concepts in both curricula and teaching in engineering education in order to prepare learners to understand the nature and safety of using nanotechnology for developmental purposes.
To create a close and advance relation between engineering education and African society development, progressive institutes and universities have established nanotechnology education initiatives in order to get modern specific knowledge for nanotechnology future. Engineering educators likewise are interested in research to discover the effective theory and practices of nanotechnology education including curricula, teaching methods, equipment, and evaluation practices. It is also necessary to focus on promotion of nanotechnology achievement and thinking toward advanced science in order to help learners to consider investing it in developing their societies. Accordingly, some researchers have studied the integration of nanotechnology concepts into curricula and teaching activities through various education levels. For example, Shalaby (2012) incorporated suggested unit for developing nanotechnology concepts and environmental thinking for secondary school students. Drane et al. (2009) conducted a study to evaluate the efficacy and transferability of a nanoscience module in North western University to face the problem of a lack of instructional materials, and to add an effective instructional materials focus on nanoscience. Brockway et al; (http://www.stevens.edu/sit/, 2009) developed Nanoscale Interdisciplinary Research Project (NIRP) at Stevens Institute of Technology to develop, integrate, and pilot curriculum modules in high school science classes in order to train persons for occupations in business and manufacturing as well as research and development; while Uddin and Chowdhury in (2001) examined the integration of nanotechnology into the undergraduate engineering curricula to provide an interdisciplinary education for engineering students to apply knowledge in design, analysis and manufacture of nanocomponents, nanodevices, and nanosystems fields.

The conclusions of those researchers confirmed the importance of incorporating nanotechnology concepts into engineering curriculum for development of engineering education. This confirmation needs a global trend to integrate nanotechnology concepts into education systems through curricula and teaching to help learners understand and apply concepts of advanced technology for developing their African societies.

1.1 The statement of problem
There is an educational need to incorporate nanotechnology education into engineering curriculum and teaching for advancement purposes, using modern knowledge in nanotechnology field to cover the lack of learning material in that area especially in engineering education. Some researchers have confirmed this and have indicated the importance of incorporating nanotechnology concepts in various educational stages covering wide range of educational objectives (Uddin
and Chowdhury, 2001; Zheng et al., 2009, Mehta, 2009, Winkelmann, 2009 and Shalaby, 2012). Therefore, it would be useful to discover modern concepts in curriculum and teaching in engineering education including both the nature and the characteristics of nanotechnology.

So, the main question of this research is: What is the effectiveness of nanotechnology education for advancement of engineering education?

This is divided into sub-questions:
1. What is the effectiveness of the nanotechnology curriculum for advancement of engineering education?
2. What is the effectiveness of the nanotechnology teaching for advancement of engineering education?

1.2 The importance of the paper
Engineering education needs to be developed in its curriculum and teaching activities in order to keep at pace with the international development and respond to the current problems and challenges facing engineering learning in African institutes. The present paper overcomes the drought of related literature; rather, it evaluated the effectiveness of nanotechnology education on advancement of engineering education. Exploration of modern concepts in nanotechnology covering both curricula and teaching in engineering and addressing the lack of nanotechnology in engineering education on the other hand, guidance of the nanotechnology education efforts towards engineering advancement, development of African societies, and avoiding negative and adverse nano-applications in society development as well.

1.3 Theoretical background
Theoretical background includes three main dimensions in responding to the questions of the paper namely, nanotechnology in engineering education, nanotechnology curriculum in engineering education, and nanotechnology teaching in engineering education. In addition, achievement and thinking towards advanced science and advancement of the civic society is considered as of great importance.

2.0 NANOTECHNOLOGY IN ENGINEERING EDUCATION
Nanotechnology is modern science that deals with the evolution of solutions to societies problems: climate change, energy renewal, water management, health care and nutrition. Education can invest in a nanotechnology revolution for social development. This development can be achieved via preparing both institutions and individuals to deal with nanotechnology culture effectively. Nanotechnology
education should therefore start from kindergarten and continue to university. As nanotechnology is a major discovery, some institutes are interested in studying nanotechnology education widely. For example, Roco (2002), together with the National Science Foundation (NSF), explored curriculum development, courses offered in universities, education training centres and networks, technological education, and student fellowship programs etc.

Instructional system needs to develop learning strategies continuously in order to integrate the techniques that target international challenges, whether related to emerging scientific concepts or investing in learners' abilities. Drane et al. (2009) suggested that education should focus on nanoscience, and that lack of educational materials prevents educators from providing basic concepts and ideas of nanoscience, as nanotechnology education demands creating methods and means that are effective in teaching those objectives.

Accordingly, some researchers are interested in studying nanotechnology education through learning stages. For instance, Ernst (2009) discussed the importance of accelerating nanotechnology education for professional knowledge and skill. These lines of technological discovery and improvement continue to unlock new content for classroom incorporation. Jackson et al. (2007) and Vanasupa et al. (2006) reported that education must not only keep pace with trends in technology, but also lead and foster this growth in order to face the inherent challenges of teaching any emerging technology like nanotechnology. Those researchers have pointed out that current educational interest focuses on nanotechnology education, and that future studies will need to consider nanotechnology education development.

2.1 Nanotechnology Curriculum and Teaching

Engineering education system is mainly responsible for tackling current changes and lack of modern technology facing African engineering societies; educationally it is important to have modern technology expanded internationally. In other words, curriculum development is one of the domestic and international requirements for educational advancement (twenty two conference for Egyptian Council for Curriculum & Instruction, 2012; Egyptian Society for Science Education (ESSE, 2007). So, incorporating modern technology into curriculum is the first step towards achieving that goal. Some studies and researches focused on that issue. For instance, (Ismaeal, 2010, Farag, 2008)

Regarding development of curriculum and teaching in engineering education, both Al-Akter (2008) and Ismaeal (2007) discussed that modern curriculum and teaching is effective approach for educational developing in engineering
education. So, it is vital to indicate that philosophy of education suggests that there are two dimensions to science; the curriculum as a content of learning, and the teaching as a method of learning. The importance of curriculum relates to cognitive, psychological and physical learning domains. While the importance of teaching refers to study activities that enable students to achieve learning domains. The following two main points explain these concepts.

2.2 Nanotechnology Curriculum in Engineering Education

Nanotechnology curriculum consists of two main processes related to engineering education. They include preparing and organising of nanotechnology concepts for formulating engineering curriculum as well as the nature of a nanotechnology curriculum which is based on technological knowledge that has been generated using both laboratory experiments and high-tech equipment. Therefore, nanotechnology curriculum should be organised technologically. This can be done through agreement of form and content bearing in mind the nature of nanotechnology.

The criteria of nanotechnology curricula consists of instructional materials used in writing, recording, storing, transferring and presenting of information that are used for teaching activities. Content criteria consists of formulating and organising information in books and learning texts used for learning activities, as illustrated by the following:

2.2.1 The form of a nanotechnology curriculum

Regrettably, there is a lack of learning resources in nanotechnology especially in engineering education field as there are insufficient direct resources nanotechnology educations. This may refer to the modernity of nanotechnology as a science. In this respect, some researchers identified the availability of labs, resources, and necessary materials for Nano-Sense activities through nanoscale science and technology (NS&T), research, and education, as areas of high priority, while the comparative lack of educational materials aimed at familiarising students with basic concepts of nanoscience has prevented educators from providing systematic instruction. This potential problem is true in all levels of education including college and university (Drane et al; 2009, Schank et al; 2009).

Suggesting the relationships between the nature of nanotechnology engineering and suitable educational materials aiming to facilitate learning in engineering classrooms, Drane et al. (2009) and Jackson et al. (2007) suggested that nanotechnology education needs learning materials for students that teaches about the nature of how small or large things are and how we are going to be able to teach students about how small things are at the nanoscale. At the same time,
nano-focus learning materials are effective in helping undergraduate students learn key ideas in nanoscience. Moreover, most researchers face the problem of lack of adequate nanotechnology materials, often making it difficult to teach. Therefore, nanotechnology learning resources can be divided into three categories in engineering education: the learning texts e.g. (e-books, web based-courses, e-journals, interactive media and modules), learning equipment e.g. (laboratory devices, virtual labs, screening tools, machines, and materials) and learning displays and exhibits e.g. (films, presentations, photos, and samples).

In this respect, Jackson et al. (2007), has developed equipment and materials at the Rochester Institute of Technology to provide an appropriate nanotechnology environment. For example, scanners, microscopes, and scanning thermal microscopy with nanotechnology would enable student image, measure, and manipulate objects in the nanoscale world. Meyyappan (2004) used learning equipment focused on optical, scanning, transmission electron microscopes, and various nano materials; and used videos depicting what happens when a nanotube is bent, stretched, compressed or twisted. These examples illustrate the mechanical properties that are essential to nanotechnology education.

It is clear that the nanotechnology engineering curriculum form affirms using modern, electronic and actual tools to give the learners both first-hand experience and a true sense of nanotechnology-information. Therefore, the implementation of these ideas requires building a nanotechnology curriculum to attain effective learning.

### 2.2.2 The content of a nanotechnology curriculum

Nanotechnology needs to be studied for the knowledge, practice as well as production of engineering materials. Also, modern characteristics of nanotechnology materials and particles contain unknown concepts which require research for purposes of discovering, investing, and generalising. In other words, nanotechnology engineering curriculum that includes effective content enables learning and teaching objectives. Vanasupa et al. (2006) suggested that nanotechnology courses that create knowledge are particularly significant. For example, gold nanoshells for cancer treatments, molecular manufacturing, tissue engineering of vital organs, and micro fluidic glucose, indicate that modern nanoscience can be used to establish a curriculum which reinforces learning and encourages building positive attitudes to develop society and future.

At the same time, contemporary concepts of nanotechnology excite learners toward investigation and inquiry according to the temporality of the information that is taught. This is consistent with the millennium educational objectives aiming to present open opportunities to learners to master the cognitive,
psychological, and physical learning domains. Some researchers like, Vanasupa et al. (2006) have noted and explored the relationship between nanoscience and learning to investigate those activities that engaged students in the process of applying their knowledge, and promoting cognitive functioning levels such as application, synthesis, analysis, and evaluation. This has reinforced the importance of nano-curriculum content to encompass cognition and psychomotor learning domains that already match the mental and physical abilities of learners.

The study of materials by nanotechnology is rare in engineering education mentioned before, a little bit of researches discussed nanotechnology educational criteria (Ernst 2009, Bowles, 2004). So, it is vital to suggest that there are two main content criteria towards building an effective nanotechnology curriculum, namely formulating and organising. Formulation of concepts according to make-up of the information involves the gradual arrangement of concepts from small facts to the big concept, and expanding from specific concepts to abstract ones. This is consistent with the hierarchal planning principle of curriculum construction. Consequently, the content of a nanotechnology curriculum can be learned logically.

Organising is building the content of an engineering curriculum based on effective approaches which may be traditional, inquiry, problem-solving, or environmental. This helps organise the nanotechnology curriculum and reinforces discipline through both learning and teaching activities systematically. Some studies organised nanotechnology content aimed at high achievement of educational objectives. For example, Hersam et al. (2004) attempted to organise the nanotechnology content of an undergraduate engineering course according to two approaches- cooperative learning and problem-based learning- and described how these ideas can be effectively applied to nanotechnology engineering education. On the other hand, Drane et al. (2009) developed a nanoscience module for college students and implemented it in a non-major science course to overcome traditional curriculum preparation, and to address the lack of educational materials. This affirms the importance of content criteria of a nanotechnology curriculum for both actual learning practices and authenticity.

In conclusion, content criteria should be considered when preparing a nanotechnology curriculum, whether using traditional, laboratory, or e-learning resources. Ignoring these criteria will result in learners dealing with problems of traditional curriculum and learning. Also, this will constrain their learning and restrain them from attaining knowledge.
2.3 Nanotechnology Teaching in Engineering Education

Nanotechnology education needs special teaching methods, procedures, and equipment, while at the same time considering both teachers' and students' styles and abilities. Reviewing nanotechnology education literature, Ernst (2009); Mark, (2004) and Jackson et al. (2007), all opined that the knowledge and nature of nanotechnology have special characteristics that need to be cared for during teaching and learning. These characteristics relate to modernity, experience, concepts, and high-tech aspects of nanotechnology. The following examples illustrate this point.

2.3.1 Knowledge modernity

The modernity of nanotechnology knowledge, especially in contemporary engineering education reflects the modern characteristics of nanotechnology that have both new and high qualitative and quantitative properties. Therefore, nanotechnology knowledge contains advanced concepts including non-traditional facts. Although, nanotechnology is produced from materials that have original properties, the final products of nanotechnology have modern characteristics totally different from their original elements or parts. Therefore, educators must provide the environment and integrative strategies that excite students to deal with modern knowledge and new characteristics of nanotechnology via discovering, understanding, and achieving.

Teaching strategies should also allow students studying engineering to keep pace with modern nano-concepts already generated from the same technologies, whether found in libraries, institutes, from experts or laboratory experiments, as well as others. Foley (2006) affirmed the need to provide nanotechnology education in the United States with a technological infrastructure to develop nanotechnologies which have helped high-technology talents achieve global dominance in modern science, technology, and engineering. This illustrates the relationship between technology and the study of the modern science.

2.3.2 Field-laboratory experience

Field and laboratory experience of nanotechnology teaching is of importance when considering the original location of the nanotechnology elements and the unique methods that were used to discover them from the depths of the earth. Educationally, it is essential to use the same methods during teaching of nanotechnology in engineering lessons. This requires designing the learning environment, integrating both field and laboratory studies that include resources that are similar as much as possible to the original nanotechnology.

To address this, Bowles (2004) demonstrated the inquiry approach of laboratory teaching through teaching chemical reactions via lessons about nanoshells cancer
treatment at U.S. high school. Others, such as Jackson et al. (2007) succeeded at curriculum reform research by including a new nano-characterisation laboratory study for microelectronic engineering and nanotechnology education undergraduates and pre-college students at the Rochester Institute of Technology, confirming that teaching nanotechnology effectively requires fusing field and laboratory experiences.

2.3.3 Interdisciplinary concepts
Nanotechnology materials have unique characteristics that should also be considered educationally in engineering classrooms. For example, in order to deal with both the accurate materials and fine particles of interdisciplinary concepts through nanotechnology teaching, it is essential to equip the learning environment with audio and video tools which clearly record and present the construction and activity of nanotechnology units in their environment. In other words, nanotechnology teaching uses electronic and virtual simulations to tackle both decomposition and separation of molecules or overlapping interrelationships between particles and atoms of nanotechnology materials. Using these media will help define the behaviour and evolution of nanotechnology interactions from start to finish, facilitate in teaching, and compensate for the lack of adequate learning materials in the nanotechnology classroom; Drane et al. (2009).

2.3.4 High-tech approach
High-technology in nanotechnology teaching in engineering affirms using information technology and communication (ICT) in both learning and teaching activities. Therefore, educators and curriculum designers should integrate ICT tools into nanotechnology learning environments. For example, e-resources, online “being online”, digital cameras, scanners, as well as other high-tech equipment, enable both teachers and learners to perceive, manipulate, and discover quality teaching processes. Bowles (2004) put into practice a nanotechnology curriculum using information - technology approach toward preparing classrooms for Chemistry and Physics classes using technological equipment.

It is clear that, multiple approaches and methods in nanotechnology teaching are vital to develop the field of nanotechnology. Hersam et al. (2004) found that the design of an engineering course can bring together a range of non-traditional pedagogical practices, including collaborative – learning, problem-based learning, peer assessment, and interdisciplinary approaches. Doing so may serve to construct a learning environment in which students are not only exposed to scientific and engineering issues of nanotechnology but also develop the interpersonal and critical evaluation skills necessary for effectively advancing nanotechnology in the 21st century.
2.4 Achievement and Thinking towards Advanced Science

Achievement and thinking towards advanced science is very essential in engineering education. Achievement due to nanotechnology enables students to know new technology, understand its characteristics and nature, and implement their theoretical perception during new experimental situations. Thinking towards advanced science helps students to create new ideas, making inquiries regarding the contemporary technology they faced, and build related perspectives and hypotheses that can be measured. This will help develop general concepts for solving societies’ problems and developing their life aspects technologically. Ho et al. (2010) found that nanotechnology study encourages students to make cognitive processing of information and hence reinforcing their achievement and thinking, as well as to constitute scientific attitudes towards nanotechnology.

Therefore, although learners are expected to know about basic science to attain very essential objectives, they are also required to be able to achieve and think about advanced science, and to keep pace with modern and global objectives, achieving its facts, interactions, and thinking about its positive and adverse usages in their society context.

2.4.1 Thinking and nanotechnology in engineering education

It is believed that both achievement and thinking occur and are shaped by the technology embedded in the learning situation, that enrich learners’ senses, making suggestions and brain storming around the supposed hypotheses and ideas. Bernhard (2007) believed that thinking can’t happen in isolation. Human contacts with reality which is always mediated and technology offers one form of mediation in education and are present where thinking through progressed technology is central to design of the learning environment. Accordingly, nanotechnology is a medium that tending to excite thinking for learners. Thinking in this context could be divided into two branches based on the technology included in the learning environments.

2.4.2 Classroom technology-thinking

This is where learners practice thinking processes during teaching activities in engineering education. They receive instructions which direct them to study and research about nanotechnology, dealing with internet, teaching presentations, and the other technological resources. Visual perception and logical thinking are being practiced by learners during their interaction with instructional technology. They construct awareness by nanotechnology and its importance to society development. Deitrich (1995) pointed out that thinking through technology is designed to be a critical introduction to the philosophy of technology.
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King et al; stated that classroom teachers recognise the importance of having students develop higher order thinking skills, they design technology giving students opportunities to recall both critical and creative thinking, and to apply higher order thinking skills to answer the suggested question or solve the problem. This thoroughly reinforces the existed learning relationships between nanotechnology and thinking skills, especially that directed towards advanced science like engineering.

2.4.3 Laboratory technology-thinking

Laboratory integration into nanotechnology education is putting learners into practice in thinking where technology and problems are provided for experimenting and getting solutions. Bernhard (2007) confirmed learning through technology in lab, where both knowledge and thinking are modes of experience; they are special kinds of mental operations thoroughly embedded in experiential situations. So experimental thinking is essential to nanotechnology education in laboratory environment, where the learners implement their theoretical understanding by manipulating experiments technologically.

To this end, the University of Cambridge (www.cie.org.uk, 2013) department of engineering education incorporated problem solving, critical thinking, and applied reasoning into laboratory syllabus for international examinations, encouraging learners to understand and apply confidently in argument and reasoning regarding advanced knowledge. Hence, integration of both classroom and laboratory technologies into nanotechnology education are important to help learners practically in achieving and thinking towards advanced science.

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ABSTRACT
Engineering education provides a thorough and systematic training in the design, development, maintenance and management of complex technical systems. While education provides the necessary technical depth to graduates, many technical systems are best understood from experimental, simulation or heuristic approach. System Dynamics is a well formulated methodology for analysis, problem solving, and simulation of the components of a system including cause-effect relationships and their underlying mathematics and logic, time delays, and feedback loops. Developed by an engineer, it is being used mainly in the social and behavioural sciences for strategic planning purposes. It began in the business and industry world, but is now applied in engineering education and practice and in many other disciplines. Recent advances have demonstrated the ability of the System Dynamics methodology in the study of complex engineering systems and to help in the understanding of such systems. This paper reviews the basic principles and conceptual ideas underlying the System Dynamics modelling approach to system studies. The applications of System Dynamics to the modelling of real-world engineering systems are presented. Modern engineering practice is often multi-disciplinary in nature and demands holistic approach that is easily handled through System Dynamics. The paper shows how System Dynamics (SD) can be employed for engineering education to cope with the dynamics of such multi-disciplinary complexity.

Keywords: System Dynamics, Engineering Education, Modelling, cause-effect, scenario experimentation

RESUME
L’éducation en sciences de l’ingénieur fournit une formation approfondie et systématique dans la conception, le développement, la maintenance et la gestion des systèmes techniques complexes. Alors que l’éducation fournit la profondeur technique nécessaire aux diplômés, plusieurs systèmes techniques sont mieux compris à partir de l’expérience, de la simulation ou d’une approche heuristique. System Dynamics est une méthodologie bien élaborée pour l’analyse, la résolution de problèmes et la simulation des composants d’un système, incluant les relations de cause à effet ainsi que la mathématiqueet la logique sous-
jacentes, les délais de temporisation et les boucles de rétroaction. Développée par un ingénieur, elle est utilisée principalement dans les sciences sociales et comportementales à des fins de planification stratégique. Elle a commencé dans le monde des affaires et de l'industrie, mais est de nos jours appliquée dans l'éducation en sciences de l'ingénieur et dans la pratique, mais également dans bien d'autres disciplines. Des progrès récents ont démontré sa capacité dans l'étude des systèmes d'ingénierie complexes et la compréhension de ces systèmes. Cet article examine les principes de base et des idées conceptuelles qui sous-tendent l'approche de modélisation des systèmes dynamiques dans l'étude des systèmes. Les applications de System Dynamics à la modélisation des systèmes d'ingénierie réels sont présentées. La pratique moderne de l'ingénierie est souvent multidisciplinaire par nature et exige une approche holistique qui est facilement appréhendée à partir du System Dynamics. L'article montre comment cette méthodologie peut être utilisée dans l'éducation en sciences de l'ingénieur afin de faire face à la dynamique d'une telle complexité multidisciplinaire.

Mots-clés: Systèmes complexes, éducation en sciences de l'ingénieur, modélisation, cause-effet, scénario d'expérimentation.

1.0 INTRODUCTION
Mathematical analysis and modelling has a long and important history in engineering education. Tools have been developed to handle the diversities involved in engineering analysis and modelling. An important feature of modelling in science and engineering is its formal character. Computer modelling in particular is assumed to involve many components some of which a student can only learn at a stage during his college or university education. These components include subject matter, analytical and numerical analysis, and computer science. As a consequence, students learn modelling of complex systems and processes late into their course of study in the university (Fuchs, 2006).

The diversity and complexity of the traditional forms of modelling call for a simplified methodology. This can be found in system dynamics modelling. System dynamics tools allow for an intuitive approach to the modelling of dynamical systems from any field of knowledge where there exists, a feed-back situation. System Dynamics modelling can easily be deployed even by young learners (Forrester, 1992). According to Meadows (1991), “System dynamics is a software-based technique for thinking and computer modelling that helps its practitioners begin to understand complex systems—systems such as the human body or the national economy or the earth's climate. Systems tools help us keep track of multiple interconnections; they help us see things as a whole”.

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System Dynamics is a well formulated methodology for analyzing the components of a system including cause-effect relationships and their underlying mathematics and logic, time delays, and feedback loops. It began in the business and industry world, but is now affecting education and many other disciplines. Having been inspired by successful policy changes in lots of fields, the system dynamics approach is now being extensively used to solve engineering related problems such as energy, climatic change, process and supply chain, industrial and environmental in Europe and America (Stedman, 2000). System dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems; literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality. Upon full development, system dynamics is a discipline with the scope of science, education, law, engineering, or medicine (Forrester, 2009). System dynamics emerges out of servomechanisms engineering, general systems theory and cybernetics (Richardson and Push, 1981). Forrester's original work stressed a continuous approach, but increasingly modern applications of system dynamics contain a mix of discrete difference equations and continuous differential or integral equations. Some practitioners associated with the field of system dynamics work on the mathematics of such structures, including the theory and mechanics of computer simulation, analysis and simplification of dynamic systems, policy optimization, dynamical systems theory, and complex nonlinear dynamics and deterministic chaos (Stedman, 2012). There is a remarkable increase in the interest and understanding of the system dynamics approach to analysis and simulation of complex system (Nuhoglu and Nuhoglu, 2007). System dynamics provides for a general and user friendly approach to the modelling of dynamical systems, irrespective of the field of application (Roberts, et al., 1994); (Fuchs, 2002). Also, system dynamics modelling has been made a part of some educational programs. There are high schools (especially in the United States 8 to 12 Grades programmes 15-18 years age brackets i.e. SS1-SS3 equivalent) that make extensive use of dynamical modelling in various subjects. System dynamics allows simple ideas to be combined into models of complex systems and processes; it makes the integration of modelling and experimentation a simple matter. It is a great educational tool and can be applied in the prototyping of complex real-life applications that is the hallmark of engineering and engineering education. In Africa and especially Nigeria, Systems Dynamics has not been conspicuously, applied in engineering, particularly at the University level and in engineering practice. This paper presents system dynamics modelling as a simple, powerful and useful tool that can be deployed to enhance and simplify the understanding of engineering systems, simulation and applications.
2.0 **THE SYSTEM DYNAMICS APPROACH**

The system dynamics approach involves:

(i) Defining problems dynamically, in terms of graphs over time;

(ii) Striving for an endogenous, behavioral view of the significant dynamics of a system, a focus inward on the characteristics of a system that themselves generate or exacerbate the perceived problem;

(iii) Thinking of all concepts in the real system as continuous quantities interconnected in loops of information feedback and circular causality;

(iv) Stocks or accumulations (levels) in the system and their inflows and outflows (rates);

(v) Formulating a behavioral model capable of reproducing, by itself, the dynamics problem of concern. The model is usually a computer simulation model expressed in nonlinear equations, but is occasionally left unquantified as a diagram capturing the stock-and-flow/causal feedback structure of the system; Deriving understandings and applicable policy insights from the resulting model; and

(vi) Implementing changes resulting from model-based understandings and insights (Richardson and Anderson, 2010).

2.1 **Modelling and Simulation**

Mathematically, the basic structure of a formal system dynamics computer simulation model is a system of coupled, nonlinear, first-order differential (or integral) equations (Equation 1).

\[
\frac{dx(t)}{dt} = f(x, P)
\]

where: 
- \(x\) = vector of levels (stocks or state variables),
- \(P\) = a set of parameters, and
- \(f\) is a nonlinear vector-valued function.

Simulation of such systems is easily accomplished by partitioning simulated time into discrete intervals of length \(dt\) and stepping the system through time one \(dt\) at a time. Each state variable is computed from its previous value and its net rate of change (Equation 2).

\[
x'(t) : x(t) = x(t - dt) + dt \times x'(t - dt)
\]

In the earliest simulation language in the field (DYNAMO) this equation was written with time scripts \(K\) (the current moment), \(J\) (the previous moment), and \(JK\) (the interval between time \(J\) and \(K\)) (Equation 3).

\[
X.K = X.J + DT \times XRATE.JK
\]

The computation interval \(dt\) is selected small enough to have no discernible effect on the patterns of dynamic behavior exhibited by the model [1981].
more recent simulation environments, more sophisticated integration schemes are available (although the equation written by the user may look like this simple Euler integration scheme), and time scripts may not be in evidence. The current simulation environments include Vensim, STELLA, PowerSim, and AnyLogic. The conceptual tools and concepts of the field include stocks and flows diagrams. These are called the Building Blocks.

2.2 System Dynamics: Stock and Flow Diagram

Stock is thought of as the accumulation of each element size in the system. There are two types of flows: inflows and outflows. Inflows are perceived as the rate at which the stock (the flow is going to) is increasing over time. Similarly, the outflow is the rate at which the stock (the flow is going out from) is decreasing. The level therefore increases with inflow and decreases with outflow. Inflows and outflows are usually not constant and vary with respect to time. As mentioned, inflows and outflows are the rates at which given quantity is being added to or subtracted from the stock. Therefore, a stock is the integral of the net flow added to the initial value of the stock. The net flow is eventually the outflow subtracted from the inflow. The net flow is therefore the derivative of the total stock with respect to time (Equation 4). As shown in Figure 1, Stock-and-flow diagram do not only show the structure’s components and their relationships, it also draw more attention to accumulation and flow processes (Stedman, 2000).

\[
\frac{d(\text{Stock})}{dt} = \text{Inflow}(t) - \text{Outflow}(t)
\]  

(4)

The graphical representation of stock and flow diagram is as in Fig. 1

Fig. 1: System Dynamics Stock-Flow Diagram

2.3 System Dynamics Basic Building Blocks

In System Dynamics modelling, there are four basic building blocks:

(i) Auxiliary/Constant,
(ii) Stock (also called box or level or state),
(iii) The rate variable and
(iv) Information links.
These building blocks are presented in Fig. 2

2.4 Control and Policy in System Dynamics

The inflow or outflow is regulated by Control or Policy indicated by the valve in the Stock and Flow Diagram. The control or policy allows a goal to be set and the contributing variables, constants and equations are used to formulate the Control or Policy objectives. This is illustrated in the filling of a cup with water Fig. 3.

Fig. 2: System Dynamics Basic Building Block

Fig. 3: Control and Policy in System Dynamics
Source: Forrester (2009)
The associated Stock-Flow Diagram associated with Fig. 3 is as shown in Fig. 4.

![Fig. 4: Stock Flow Diagram for Filling the Glass Cup](image)

*Fig. 4: Stock Flow Diagram for Filling the Glass Cup
Source: Forrester (2009)*

Filling a glass of water is not merely a matter of water flowing into the glass. There is a control of how much water. That control is the feedback loop from water level - to eye - to hand - to faucet - to water flow and back to water level. Such closed loops control all action everywhere. Figure 4 shows the simplest possible closed loop system (Forrester, 2009).

The flow changes the amount in the stock. The flow is determined by a statement that tells how the flow is controlled by the value of the stock in comparison to a goal (objective). All systems, (including engineering systems), consist of these two kinds of concepts—stocks and flows—and none other. Such a statement, that, there are two and only two kinds of variables in a system, is powerful in simplifying our view of the world (Forrester, 2009).

3.0 SYSTEM DYNAMICS IN ENGINEERING AND ENGINEERING EDUCATION

Engineering practice is about proffering solution to complex problems, while engineering education is to equip an individual with necessary tools and expertise to solve such complex problems. When a problem arises in a system, actions must be taken. However, making the wrong decision could propagate the problem, and ultimately collapse the system. Therefore, understanding the behaviours and structures of systems is essential for problem solving. In general, systems contain many complex relationships which might cause them to be nonlinear, and make it difficult for the human mind to think through the problem. Therefore, many graphical and mathematical modelling methods have been developed as potential tools to understand a system. In modelling, some insignificant relationships can be neglected to simplify the complexity of the system. Real life systems are dynamic, and therefore modelled with respect to time or space. Once the model is
fully developed, it can be defined in its most generic form to serve as a reference for other similar systems. Examples are giving to demonstrate how System Dynamics can be used to understand simple and complex engineering systems and thus enhance engineering education and practice.

3.1 System Dynamics Modelling Examples

3.1.1 Modelling of Filling the Glass Cup
In Figure 3 and Figure 4, the pictorial and the Stock and flow diagram are presented respectively. Now the analysis of the system is done, to create a simulation model in which a person fills a glass of water. It is expected or assumed, however, that the person acts logically.

To make a flow diagram,
- a mental picture of the system will have to be conceptualized
- a definition of Flows elements that vary the Level
- the rest of the elements of the system are Auxiliary variables

![Fig. 5: System Dynamics Modelling Diagram to Fill the Glass Cup](image)

![Fig. 6: Simulation Graph of the Filling Process](image)
Figure 6 is the output of the System Dynamics simulation of the model presented in Fig. 5.0. It is observed that equilibrium is reached when the capacity of the cup if full (250 cm$^3$). This is the goal expected to be achieved. The **eye-and-hand controls** assist to achieve this goal.

3.1.2 **The Bathtub**

The hydraulic metaphor of the bathtub and the system dynamics graphical representation of stock and flow diagram and the associated integral equation are presented in Fig. 7.0.

![System Dynamics Stock & Flow Diagram with Governing Differential and Integral Equations](source)

The Stock and flow diagram (simulation diagram) for Fig. 7.0 is as shown in Fig. 8.0.

![Simulation Diagram for a Leaking Bathtub](source)

The simulation diagram is used in the simulation and in understanding the filling dynamics of a container having a limited volume (100 litres in this example). In addition to its restricted capacity, the container also has a leaking drain causing a
constant OUTFLOW RATE. Since the inflow is larger than the outflow, the container will gradually fill until the state is equal to BATHTUB VOLUME. After that, the state of equilibrium is reached (Figure 9). The result of SD simulations can also be presented in Tabular form as shown in Table 1.0. The System Dynamic equation is automatically generated by the VENSIM software for this system.

![Simulation Result of Filling and Draining of a Tank (Bathtub)](image)

Table 1: Simulation Result of Bathtub Model

<table>
<thead>
<tr>
<th>Time (Minute)</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
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<td>4</td>
<td>60</td>
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<td>75</td>
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<td>6</td>
<td>90</td>
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<td>100</td>
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<td>8</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

BATHTUB VOLUME = 100 Units: Litre
inflow = inflow rate Units: Litre/Minute
inflow rate = IF THEN ELSE(State < BATHTUB VOLUME, INFLOW VOLUME, OUTFLOW RATE) Units: Litre/Minute
INFLOW VOLUME = 20 Units: Litres/Minute
outflow = OUTFLOW RATE Units: litre/Minute
OUTFLOW RATE = 5 Units: Litre/minutes
State = INTEG (inflow-outflow, 0) Units: Litre

3.1.3 Simple Harmonic Motion with Damping: Pendulum
A pendulum is another simple physical or mechanical system used to demonstrate simple harmonic motion in engineering education (Figure 10).
The study of oscillatory motions has always been motive for conflict, especially for students. What is this conflict? From the mechanical courses to study oscillation, we see systems with apparent complexity including (a) an assumed constant acceleration (b) a variables motion and (c) changing its value depending on the time. These complexities can be disconcerting for the students. This uncertainty increases when the students solve differential equations to find the motion variables (position, speed, and acceleration) and/or the dynamics variables (quantity of movement and strength), and they lose the capacity to analyze the behaviour of the variables that have an influence - or not- in the motion equation (Hestenes, 2007).

System Dynamic is presented here as an alternative tool to solve this problem and instead of causing "conflict", it will actually stimulate the interest of the students in the subject. The oscillatory motion is a system that describes a motion formed by a pendulum with the following characteristics:

- a body of mass \( m \),
- suspended from the extreme eng of an ideal spring with an elastic constant \( k \),
- when this is perturbed (elongation or compressed) respect its position of balance \( x_0 \),
- a distance \( x \)

The forced oscillatory motion is produced by Equations 5, 6, and 7.

An Elasticity: \[ -kx \] (5)
A Frictional Force: \[ -bv \] (6)
Harmonic Force: \[ F(t)\cos(wt) \] (7)

Where:
- \( b \) = change of mass per unit time
- \( v \) = velocity
w = the frequency of variation of the force
\( t = \) time
\( F = \) Maximum intensity of acting Force

The equation of motion is:

\[ \frac{d^2}{dt^2} + kx - b \frac{dx}{dt} + F(t) = m \frac{d^2x}{dt^2} \]  \hspace{1cm} (8)

The pendulum equation of motion is nonlinear and it therefore exhibits rather complex behaviour. It can swing back and forth. It has equilibrium points, which can be stable or unstable. Its motion depends decisively on initial conditions in terms of initial angle and angular velocity. The motion is damped by air friction on the pendulum and gravity causes it to move towards the lower dead center (Bussel, 2006).

A system dynamics model can correctly describe the complexity of the behaviour of the pendulum oscillatory motion. The SD model diagram to illustrate the dynamics of the motion is as shown in Fig.11. The model can be used to analyze the motion variables (position, velocity and acceleration). It can also be used to investigate dynamics of quantity of movement and strength.

It is seen from the SD model (Fig. 11), that motion is based on four **LEVELS OR STOCKS:**

i. the quantity of the movement \( p(x) \), is modified by the flux \( \frac{dp(x)}{dx} \) (the strength in \( x \));

ii. the position \( x \) that is modified by the flux \( \frac{dx}{dt} \) (the velocity in \( x \));
iii. the velocity $v(x)$, that is affected by the flux $\frac{dv(x)}{dt}$ (the acceleration in x); and
iv. the mass $m$, affected by the flux $\frac{dm}{dt}$ (it will be assume that the mass does not change with time in this example).

Also from Fig. 7, the acceleration is influenced by the following auxiliary variables:
i. the elastic constant of the spring $k$
ii. the mass $m$
iii. the difference or Gap between the position $x$ (LEVEL) and the position of balance or equilibrium $x_0$
iv. the constant of damping $b$
v. the Force or strength $F$ and
vi. the phase $o$, which is the same as the product of frequency $w$ and time $t$

3.2 Heuristic Investigation: Gaining Insight into the Systems through Simulations (Scenarios)
The heuristic power of System Dynamics in the investigation of behaviour of system is demonstrated by the following results of simulations. This is also, referred to as Scenario experimentations.

3.2.1 With Initial Force 700 Dyne
The following parameters were used for the start of the simulation experiments

- $b =$ 35 g/s
- $F =$ 700 Dyne (1/1000N)
- $M =$ 50 g
- Initial Time $=$ 0 second
- Final time $=$ 20 second
- $k =$ 500 Dyne/cm
- TIME SET $=$ 0.0135 second
- $w =$ 750 1/second
- $x_0 =$ 0 cm
The results generated are as shown in Fig. 12 and Fig. 13 for F=700 Dyne.

**Fig. 12:** Behaviour of Motion Parameters with Initial String Strength of 700 Dyne

**Fig. 13:** Behaviour of Dynamic Parameters with Initial String Strength of 700 Dyne
3.2.2 With Initial Force 0 Dyne
Using the same parameters as in (a) above, and changing the Force to 0 Dyne, the results of the simulation are as shown in Figure 14 and Figure 15.

Fig. 14: Behaviour of Motion Parameters with Initial String Strength of 0 Dyne

Fig. 15: Behaviour of Dynamic Parameters with Initial String Strength of 0 Dyne
The Figure shows the oscillation and damping process in respect of displacement (acceleration and velocity). From Figure 15 above, all the parameters come to equilibrium and rest at zero. However, it takes longer time for the pendulum to come to rest when the initial Force is high.

The Force $F$, initially chosen as 700 Dyne for the Motion and the dynamics variables respectively, is observed to produce an initial amplitudes of $dvx/dx$, $vx$, and $x$ with magnitudes of ±20cm, ±60cm, ±400cm respectively. When the Force was changed to 0 Dynes, it was observed that the amplitude for $dvx/dt$, $vx$, and $x$ became ±60cm, ±200cm, ±200cm respectively. Other parameters that will give insight into the complexity of the oscillatory motion can be investigated without mounting an experiment. The results also showed clearly, that when a greater Force is applied, it will take a longer time for the pendulum to come to rest. Similar observations are made for the dynamic parameters of $dpx/dt$ and $px$. These are clear demonstration of the great educational advantage of System Dynamics.

### 3.3 System Dynamics and Project Management

All engineers are involved in some kind of Project Management. Projects are of various kinds; carrying out a field survey, traffic counts, setting up a research experiment, writing a grant proposal, building a road, a house to building a rocket or a nuclear power plant. They all have very similar dynamic characteristics. These are scientific procedures of project management that engineers must follow in order in to achieve a business case (goal). In fact, the more an engineer grows in the career, his pre-occupation might be limited to Project Management. Projects that, relative to the initial goals and expectations, take too long, cost too much, have poor quality, and compete too little are common in our environment.

System Dynamics (SD) model are often developed to help understand the process involved in getting a project executed. The development of the model will also show that SD can be used to introduce complex subject in a simple manner in engineering education. Assume the Project to be developed is the design of a new a building project, though the model is directly applicable to any other kind of project. The model developed in stages to appreciate how a simple SD model can become a complex one.

#### (a) Model 1: Initial Project Definition

The most fundamental characteristics of any project are the establishment of a business case and the project management tool to achieve the business case. The basic Project Management concept is depicted by the SD Stock and flow diagram in Figure 16.
Parameters Governing the Project:

- **FINAL TIME** = 24 month
- Initial Project Definition = 1000 Tasks
- Work flow = 100 tasks/month
- **INITIAL TIME** = 0 month
- Time Step = 0.0625 months (2 days)
- Initial Work = 0
- Remaining work = -work flow

According to Fig. 17, the project is expected to have been accomplished in 24 months. It also showed that the more tasks are accomplished, the less the works was remaining to be done. This is an extreme ideal situation in Project Management.

**Model 2: Stopping Work**

There are some ways to shut down the project model. One simply is to stop simulating when the project is done; the other one is to create a variable "project is done" to control this. This last option will provide us with a mechanism for "de-scoping" or "close" the project if there are scheduled or budget problems. The concluded project is then taken as a "Phase" and the remaining of the project can take place as another project in the "next phase" (Fig. 18).
It is observed (Fig. 19) that the project is already closed at the 10th month but it does not mean that the project is completed as conceptualized. It might just mean the completion of a Phase.

(c) Model 3: Errors and Rework
So far, it has been assumed that the work is being done without error. In general and in practice, this is not true. There are a number of places where errors can occur, including miscommunication among personnel, technical oversight, selection of inappropriate technology (skylight) or flat roof for tropical conditions, and oversights or just plan mistakes. However, when errors occur they are not, immediately discovered. Errors remain undetected until there is a review or integration activity that brings them to the limelight. The situation of error and rework is modelled in Fig. 20.
The simulation results are as shown in Fig. 21. It can be seen that the Tasks to be accomplished increased from 1000 to 1020 tasks. Undiscovered Rework increased up to about the 10th week in the project life cycle before it starts to decline. Work remaining did not become zero until about 11th week. And the total work did not get accomplished until about 12th week. This is the ideal situation in Project Management. By using System Dynamics the students and indeed engineering practitioners can simulate different scenarios and thus capture the various dynamics that can come to play in Project Management.
4.0 DISCUSSION AND CONCLUSION

System Dynamics has been presented as a useful tool to solve complex engineering problems. SD is shown as a heuristic method of investigating any system with feedback loop. It is proposed, here, that we might want to consider system dynamics modelling to introduce learners to the art and practice of creating dynamical models. Unlike other methods and tools, the programs created for system dynamics modelling make use of a metaphor, which resembles most closely the one we humans use to conceptualize phenomena and experiences ranging from fluids, electricity, heat, and motion etc. Along the lines discussed in this paper, system dynamics program would be a veritable tool with the aim of enhancing engineering education.

This paper has tried to demonstrate that system dynamics modelling can play an important and constructive role in understanding subjects taught in the engineering classrooms. If modelling is not an activity that follows after learning but rather, is used, as a Method for learning, we should consider carefully what system dynamics has to offer. In an important series of papers, David Hestenes has made it clear that modelling is a path to learning (Hestenes, 1992; 2006; 2007). Modern computer tools have made explicit modelling of physical, chemical, biological and engineering applications accessible to a much larger audience than would have been considered possible only a few years ago. There is hardly a simpler method of integrating the lab with model construction than that offered by system dynamics modelling tools. In conclusion, the statement made by Meadows in 1991 is apt. “System dynamics is a set of techniques for thinking and computer modelling that helps its practitioners begin to understand complex systems—systems such as the human body or the national economy or the earth’s climate. Systems tools help us keep track of multiple interconnections; they help us see things whole”.

Engineering has become truly complex and divided. It is time we help our students to see them as a whole.

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Vensim: Vensim:http://www.vensim.com/ There is a free (but limited) fully functional version of the program on the web.
ACADEMIA – INDUSTRY INTERACTION IN ENGINEERING EDUCATIONAL TRAINING: A KEY TO CAREER AND COMPETENCIES DEVELOPMENT

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ABSTRACT
Knowledge transfer between industry and academia is a key to enhancing training and development of career and competencies in both sectors. The latter play critical role in developing knowledge – based economy and sustainable competitive advantage. Competency profiles assist in effective learning and development by identifying the behaviours, knowledge, skills and abilities that are necessary for successful performance in a job or assignment. Therefore, the industry and the academia need to be in constant interaction with the aim of developing new data, methods and technology. Often academics in Nigeria are involved in academic research which may not have practical applications in the industry. To add value to the nation’s economy, much attention must be paid to the educational systems. In an attempt to explore the above issues and determine the best practice components, the authors conducted a review of competency – based learning and competency – based education and training programs and explored the programs available and mode of delivery in the Eastern Europe and the defunct Soviet Union as well as UK. The authors’ experiences as students, industrialists and academicians were handy for identifying the gaps, shortcomings and areas in need for incorporation and development in the Nigerian/African system of training of engineers. The paper assessed how curriculum and/or learning program design and development could be improved with the introduction of competency – based management as practised in the Universities; case study in the UK. Recommendations and guidelines to government and institutional administrators that will assist to eliminate the obstacles to career and competencies development in Nigerian/African engineering educational training and learning programs were provided, which will enhance the entrepreneurial spirit and job creation by engineers.

Key Words: learning and training, career, competency, curriculum, entrepreneurial spirit, job creation.

RESUME
Le transfert de connaissances entre l’industrie et le milieu universitaire est une clé pour améliorer la formation et le développement de carrière et des compétences dans les deux secteurs. Ces derniers jouent un rôle essentiel dans le développement de l’économie du savoir et constituent un avantage concurrentiel durable. Des profils de compétences favorisent un apprentissage et un développement efficaces à partir de l’identification des comportements, des
connaissances, des compétences et des capacités qui sont nécessaires pour l'exécution réussie d'un emploi ou d'une tâche. Par conséquent, l'industrie et le milieu universitaire doivent être en interaction constante afin de développer de nouvelles données, méthodes et technologies. Souvent, des universitaires au Nigeria impliqués dans la recherche scientifique peuvent manquer d'expérience et de pratique industrielles. Afin d'ajouter de la valeur à l'économie nationale, une attention particulière doit être accordée aux systèmes éducatifs. Dans une tentative de traiter ces problématiques et de déterminer les composantes des meilleures pratiques, les auteurs ont mené une étude de l'apprentissage par compétences, de l'éducation par compétences et des programmes de formation, et exploré les programmes disponibles ainsi que leur mode d’implémentation en Europe de l’Est, en ex-URSS et au Royaume-Uni. Les expériences des auteurs en tant qu’étudiants, industriels ou universitaires ont permis d’identifier les lacunes, les insuffisances et les zones nécessitant l’incorporation et le développement dans le système nigérian/africain de formation des ingénieurs. L'article a permis d’évaluer comment la conception et le développement des curricula et/ou d'un programme de formation pourraient être améliorés par l'introduction du management par compétences tel que pratiqué dans les universités sur une étude de cas au Royaume-Uni. Des recommandations et lignes directrices pour le gouvernement et les administrateurs des établissements qui aideront à éliminer les obstacles au développement de carrière et de compétences dans les programmes nigérians/africains de formation et d'apprentissage dans l'éducation en sciences de l'ingénieur ont été proposées, ce qui permettra d'améliorer l'esprit d'entreprise et la création d'emplois par les ingénieurs.

Mots-clés: apprentissage et formation, carrière, compétences, programmes, esprit d'entreprise, création d'emplois.

1.0 INTRODUCTION
The last time Nigerian engineers engaged in active discussion of engineering on a large scale was far back in July 1991 at a National conference jointly organised by the Council for the regulation of Engineering in Nigeria, (COREN) and the Committee of Deans of Engineering and Technology of Nigerian Universities (CODET). Over twenty-one years ago, this conference hosted the Future of Engineering Education in Nigeria. And annually the Hosting of the African Regional Conference on Engineering Education to discussed ways of solving the problems of engineering education in all its ramifications. Many papers were presented by esteemed Engineers of Fellows of Academy of Engineering, reminding us the importance and the relevance of many areas that needs considerations viz: policy options for sound engineering education, methodology, curriculum development, instructional aids, staffing, continuing education and Training. One of the presenters, Professor T.I Raji discussed in his paper;
Strategies for improving the quality of education in Nigeria, and listed varied factors militating against sound engineering education to include; inadequate teaching and research facilities, acute shortage of textbooks, referenced journals and brain drain.

Other factors listed are defects in the curriculum, low level of interaction between the Universities and industry, little or no research cooperation between the Military (who are sponsors of the largest research efforts abroad) and the Universities, and the non-chalant attitudes of students to their studies and some staffs to their work.

The Academia and the industry needs to be in constant interaction, with the aim of developing the graduating engineer to appreciate the essence of its education and the needs of the industry, after all the engineer after graduation is going to apply the education acquired to solve real-life engineering needs and problems of the larger society that he is going to work and interact, that is why? The developed countries of the world, like UK, have a growing agreement among policymakers, economic strategists and commentators that the UK’s future prosperity will depend on the creation of a more diverse economic base. In effect, this means that the UK must create more successful high-technology businesses and industries to manufacture, build and maintain the products, infrastructure and services of the future. These innovative enterprises will build on the national strengths in science and technology, address grand challenges, boost GDP and underpin social progress at all levels\(^2\).

Engineering graduates for industry was commissioned in 2008 by the Department for Innovation, Universities and Skills – now the Department for Business, Innovation and Skills to identify how to increase the number of employable engineering graduates with the skills industry needs. Against a background where the UK competitive advantage will depend increasingly on raising the level of science, technology, engineering and mathematics skills, there was recognition that UK business and industry would be disadvantaged if not provided with an adequate supply of well educated and motivated engineering graduates.

In an attempt to explore the above issues, the authors, conducted a review of competency-based learning and competency-based education and training programs applicable in the Eastern European countries and most countries of former defunct Soviet Union by presenting the learning structure and Higher education in some Eastern European countries as well as some universities in the United Kingdom to drive home there points of industry-Academia interaction with different mode of practice applicable in the case studies explored. The authors have their educational training in the Eastern/Soviet educational system,
and today can testify, from their experience and interest of pursuit in life, based on their present work and thought process.

2.0 LEARNING STRUCTURE AND HIGHER EDUCATION IN CENTRAL, EASTERN AND SOUTH EASTERN EUROPE

In the first project report on Trends in Learning Structures in Higher Education, prepared for the Bologna Conference in 1999 ("Trends I"), Guy Haug and Jette Kirstein presented an outline of some of the main trends in the higher education systems of the EU/EEA countries. In particular, they looked at institutional structures, credit and recognition systems, quality assurance, the organisation of the academic year and similar matters.

A main purpose of the present "Trends II" report is to provide the same analysis and overview for those countries that have signed the Bologna declaration but, due to time constraints, had not been included in "Trends I". This concerns mainly countries in Central and Eastern Europe: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. In addition this group includes Malta and Switzerland. Finally, six states that have expressed interest in the process towards the creation of a European higher education area have been included in the survey: Albania, Bosnia-Herzegovina, Croatia, Cyprus, the Former Yugoslav Republic of Macedonia and the Federal Republic of Yugoslavia.

Some Eastern European countries adopted the former Soviet model of higher education, which emphasised science and engineering and an engineering curriculum that focused on training for production. In Bulgaria, for example, the fields of natural sciences and engineering were given the highest priority for enrolment quotas and generally, a 50:50 ratio of male and female students. In addition, prospective students were screened on straightforward criteria: competitive examinations and mathematics competence.

2.1 National frameworks for higher education institutions and qualifications

Diversification of institutions

As Jette Kirstein pointed out in "Trends I", two different types of higher education systems prevail world-wide, in spite of the existing diversification:

A so-called unitary or comprehensive system where most higher education is catered for by universities or university-like institutions, offering both general academic degrees and more professionally-oriented programmes of various lengths and levels;
A so-called binary or dual system with a traditional university sector based more or less on the Humboldt university concept and a separate and distinct non-university higher education sector. In all European countries, the need for diversified offers in higher education to serve the different needs of students and employers has been recognised and taken into account. In the unitary system, the diversification is taken care of by a single type of institution, normally the university. The study programmes are therefore often much more varied in level, character and academic and theoretical orientation than in traditional universities in a binary system. Many programmes are professionally oriented. Among the countries surveyed in this study unitary systems exist today in Albania, Bosnia-Herzegovina, the Czech Republic, FYROM, Romania, the Slovak Republic and the Federal Republic of Yugoslavia. In FYROM, however, the new Higher Education Law of November 2000 calls for the creation of professional schools, thereby changing the system into a binary one.

The binary systems in some of the other countries are still in the development phase, with the new laws on higher education adopted in the 1990s providing for the possibility set up non-university and private institutions. As for Malta, higher education is just changing from a unitary to a binary system.

In binary systems developed in Western Europe, there is a traditional difference between universities offering the theory- and research-based programmes and the non-university institutions taking care of high-level professional programmes? In Central and Eastern Europe, the Soviet division of labour between universities and much specialised higher education schools (in charge of teaching) and academies (in charge of research) prevailed up to 1990. Many countries have by now re-integrated more research into the universities and are re-defining the tasks of the academies and their relationship to the universities.

Finally, as in Western Europe, there is a tendency to up-grade existing vocational and Professional institutions and to integrate them fully into the higher education sector.

The reasons for these developments are the same as those listed by Jette Kirstein for the EU/EEC countries:
- to offer more professionally-oriented and economically relevant types of education
- in order to meet a labour market demand for such candidates;
- to cater for a growing number of higher education applicants without substantially
  Increasing governmental expenditure for higher education;
- to cater for non-traditional groups of students in a more innovative manner;
to offer primarily teaching-oriented programmes with some use of applied research; and
• to upgrade existing vocationally oriented post-secondary education.

2.1.1 Laws and other Basic regulations concerning education in Bulgaria
Higher education is governed by the Higher Education Act of 1995 that guarantees the autonomy of higher education institutions. Amendments, adopted in July 1999 and July 2000, regard the degree system and related matters.

Bulgarian higher education is largely organised in a binary two-tier system but there are still some one-tier degrees. At the university level, there are universities and specialised higher education schools (i.e. academies and institutes), the latter offering training and research only in specific fields such as science, arts, sports and defence, but conferring the same degrees as the universities. In addition, there are colleges with shorter, professionally oriented courses. They result from a re-shaping of the former semi-higher education institutions. In most cases they are incorporated into the structure of universities but there are also some independent colleges.

2.1.1. (a) The University sector
Universities and specialised higher education schools offer a Bachelor degree after 4 years and a Master degree after one additional year. In addition to these two-tier degrees, there are still some fields, e.g. in architecture, where only a 5-years Master degree can be obtained. Doctoral degrees require at least 3 years of study and research after the Master and years after the Bachelor. The Bulgarian Academy of Sciences, the Academy of Agriculture and other academic institutions may also confer the doctoral degree. Finally, there is the degree of Doctor of Sciences, corresponding to a doctor habilitatus.

(b) The non-University sector
Colleges offer after 3 years the degree of “specialist”.

2.1.2 Lithuania
The Law on research and higher education of 1991 and the Law on higher education of March 2000 form the basis for higher education. It is organised in a binary two-tier system: according to the new law of March 2000 some colleges were established in Lithuania in autumn 2000, which provide non-university type education. Up to now there are 19 state (10 universities, 5 academies and 4 colleges) and 7 non-state (4 university-type and 3 colleges) higher education institutions in Lithuania.

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(a) **The University sector**

The universities offer Bachelor, Master and doctoral degrees (including the doctor habilitatus) and also professional studies on two levels.

Academies are of the same academic status as universities, but offer a more limited range of programmes. Bachelor degrees (or equivalent professional qualifications) take 4 years. Master degrees require another 1.5 to 2 years. The doctoral degree is not considered a higher education qualification but a research degree. It should not take more than 3 years (for holders of a Master degree) or 4 years (after the completion of specialised professional studies or continuous studies in some study fields, such as law or medicine), out of which 1 to 2 years are spent in doctoral courses as a requirement for the admission to the doctoral research project.

Doctoral students may also be trained at research institutions, in cooperation with universities.

(b) **Colleges**

The colleges offer a professional qualification after 3 years (or 4 years for extramural studies).

### 3.0 A CASE STUDY OF SIX UNIVERSITIES IN THE UK ON ENGINEERING EDUCATION AND THE NEEDS OF INDUSTRY

A 2007 Royal Academy of Engineering publication, Educating Engineers for the 21st Century, reported that industry seeks engineering graduates who have “practical experience of real industrial environments”.

Specifically, “industry … regards the ability to apply theoretical knowledge to real industrial problems as the single most desirable attribute in new recruits. … In descending order of importance other relevant attributes … include theoretical understanding, creativity and innovation, team working, technical breadth and business skills”.

With these needs in mind, our paper has focused on the options for encouraging and enabling universities to develop engineering courses that include “experience-led” teaching, designed and delivered mainly in partnership with industry and business. The study review took in a wide range of experience-led higher education engineering provision – from intensively research-led programmes to employer-led foundation degrees in a broad range of university types, geographical locations (within England) and engineering disciplines.
3.1 Research Methodology
This report has been developed using a case study approach to provide an in-depth examination of experience-led engineering activity in six English universities.

3.1.1 Research questions
The study identified a key research question, derived from the project brief:
How can we enhance a sustainable world-class higher education engineering sector that meets the graduate recruitment needs of industry?

This led to a further six subsidiary research questions:
- What does industry need from engineering graduates?
- How do universities know what industry needs?
- What are universities currently doing, or developing, within their teaching that meets these needs of industry, and why?
- What difference are these activities making?
- What more/else could be done to better enable universities working together with industry to meet these needs in the future?
- How can universities and industry cooperate effectively and be best supported in this process?

These research questions provided the focus for the investigations and framed the case study approach. The questions also informed the structure of the more than eighty-five in-depth interviews that were conducted with academic staff, students, industrialists, graduates and other relevant university units (e.g. staff supports) at each of the case study universities.

The selection of the case study universities, shown in Table 1, was informed by examples of effective practice presented at a RAEng Visiting Professors’ Workshop on experience-led engineering degrees held in 2008.
Table 1: Summary of case studied institutions

<table>
<thead>
<tr>
<th>University</th>
<th>Faculty/School</th>
<th>Engineering disciplines covered in this study</th>
<th>Exemplars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aston University</td>
<td>School of Engineering and Applied Science</td>
<td>Chemical, Computer Science, Electronic, Engineering Systems and Management, Mechanical</td>
<td>1. Industrial placements</td>
</tr>
<tr>
<td>Coventry University</td>
<td>Faculty of Engineering and Computing</td>
<td>Aerospace, Automotive, Built Environment, Civil, Computing, Electronic, Knowledge Management, Mechanical</td>
<td>2. Foundation degrees in power engineering</td>
</tr>
<tr>
<td>Imperial College London</td>
<td>Faculty of Engineering</td>
<td>Aeronautics, Bioengineering, Chemical, Civil, Computing, Electrical, Electronic, Environmental, Materials, Mechanical</td>
<td>3. Activity led learning</td>
</tr>
<tr>
<td>University of Liverpool</td>
<td>Faculty of Engineering</td>
<td>Aerospace, Civil, Materials Science, Mechanical</td>
<td>4. Industrial simulation (Constructionarium and chemical pilot plant)</td>
</tr>
<tr>
<td>Loughborough University</td>
<td>Faculty of Engineering</td>
<td>Aeronautical, Automotive, Building, Chemical, Civil, Electrical, Electronic, Manufacturing, Mechanical</td>
<td>6. Large group projects</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7. Student-led activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8. Active learning (adapted from CDIO)</td>
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<td></td>
<td></td>
<td></td>
<td>9. Visiting professors</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>10. Understanding stakeholder needs</td>
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<td></td>
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<td></td>
<td>11. Live experimental laboratory (CEREB)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>12. Industrial placements (Diploma in Industrial Studies)</td>
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<td></td>
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<td></td>
<td>13. Industrial group projects (Teaching Contract Scheme)</td>
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<td></td>
<td></td>
<td></td>
<td>14. Sponsored degree programmes</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>15. Discipline-based support (engCETL)</td>
</tr>
</tbody>
</table>

Pilot case studies were first conducted at Loughborough and Coventry before the data collection method was finalised for the remaining four universities. Desk-based research was done at the same time as the collection of the interview data.

3.2 Aston University, School of Engineering and Applied Science

Aston University is a research-led institution with strong links to industry. The University is relatively small, with around 9,500 undergraduate, postgraduate taught and research students. Aston has categorised its strengths into three main areas: research, learning and teaching, and community engagement. It has succeeded in establishing strong links to the local community, with 39% of undergraduate students in 2007/08 coming from the West Midlands. The National Student Survey (NSS) shows that overall student satisfaction for Aston University’s undergraduate degree programmes was 89% in 2007/08, above the UK average of 82%, giving them the top ranking of universities in the West Midlands. The University as a whole also ranks well in a number of university league tables.
The School of Engineering and Applied Science (EAS) is made up of six discipline groupings: Chemical Engineering & Applied Chemistry; Computer Science; Electronic Engineering; Engineering Systems & Management; Mathematics; and Mechanical Engineering & Design. At undergraduate level, the usual patterns of study are 3-year BEng or BSc and 4-year MEng or MChem degrees with the option to take an industrial placement.

Nearly all of the programmes are accredited by the appropriate professional institution. The School has a strong graduate employability record, with 91% of the E&T graduates in 2006/07 either in employment or further study within six months of graduating, with 31% in E&T related jobs.

3.2.1 Overview of industry-related components within the undergraduate engineering programmes
One of the School’s key strengths is employability: “Through investing in the staff, and curriculum development. Aston has produced ever-more relevant and desirable programmes with an emphasis on employability, and involves industry in design and assessment.”(EAS - Learning and Teaching, Strategy, 2012) Local industries have assisted in the development of the curriculum. Aston’s strong employability record provides evidence that it understands the needs of industry. In addition to the normal industrial liaison committees, many staff has extensive industrial experience, both prior to their academic career and through research and Knowledge Transfer Partnerships (KTPs). This input is enhanced by industrial visitors contributing to the curriculum, providing several industry-sponsored project prizes and industrial projects and making informal presentations.

3.2.2 Effective Practice Exemplar 1: Industrial placements at Aston
Aston University pioneered placement years - one year work experiences in an industrial setting - over 50 years ago. All of the School’s six discipline groupings have a placement scheme and whilst placements are not compulsory, students are actively encouraged to take up a placement year in industry and during 2008-09 approximately 30% of EAS students found a placement. The placement year in industry allows students to better appreciate the workings of professional engineers and the applicability of their theoretical knowledge. The placement year is integrated into the curriculum, so students are prepared for it during the first two years of their degree programme by building up their employability skills. When looking for an industrial placement, students are in competition with each other and often with other universities. Typically, placements are taken after the second year of the Bachelors programmes, or occasionally at the end of the third year for MEng students.
The minimum requirement is for the student to spend 45 weeks on their placement. All participating students who pass their placement have ‘with professional training’ appended to their degree certificate as recognition of their industrial experience. Making the placement year a creditable element in the degree programme has recently been considered.

3.3 Loughborough University, Faculty of Engineering
Loughborough University is proud of its reputation for excellence in teaching and research, supported by strong and often longstanding links with business and industry. In the Times HE’s Student Experience Survey of 2008, Loughborough was the highest scoring institution in the ‘good industry connections’ category and was the top-ranked institution overall for the third consecutive year. The Faculty of Engineering comprises five departments: Aeronautical and Automotive Engineering; Chemical Engineering; Civil and Building Engineering; Electronic and Electrical Engineering; and Mechanical and Manufacturing Engineering. The Faculty hosts both the national Engineering Subject Centre and the University’s Engineering Centre for Excellence in Teaching and Learning (engCETL).

3.3.1 Overview of industry related components within the undergraduate engineering programmes
There is a well-established ethos within engineering at Loughborough that degree programmes should incorporate experience-led components and there are many examples of such components. Such commitment to industry ensures regular feedback to support the development of industry-ready graduates. Interactions with industry occur at various levels.

Formal interactions include the departmental Industrial Advisory Committees, which can help influence programme development. Industrial participation in teaching and research provides further opportunities, both formal and informal; to gain further feedback and to help develop aspects of taught programmes. Loughborough staffs are confident that this combination of formal and informal interactions works well to understand and then meet the needs of industry.

3.3.2 Effective practice exemplar 2: Diploma in Industrial Studies at Loughborough
The Diploma in Industrial Studies (DIS) is an additional qualification awarded for completion of a placement year in industry (minimum 45 weeks duration, UK or overseas) during the undergraduate degree programme. For 2006/07, uptake varied from 44% in the Department of Aeronautical and Automotive Engineering to 74% in the Department of Civil and Building Engineering. The placement usually takes place between the second and third undergraduate years. Departments typically promote and support their placement schemes using an
academic director and a placement administrator. Most departments also run placement fairs.

3.3.3. Effective practice exemplar 3: the Teaching Contract Scheme at Loughborough
The Teaching Contract Scheme in Mechanical and Manufacturing Engineering is an example of collaboration with multiple companies to provide industry-based group design projects. Currently, 14 companies and over 200 students are involved in the scheme, which operates with second and fourth year students who complete projects set by the collaborating company in cooperation with the University. In the second year module, Application of Engineering Design: Industry-Based Project, all Mechanical Engineering students’ complete projects in teams of up to four. In the final year of both Mechanical and Product Design MEng programmes, students tackle bigger projects and are organised into multidisciplinary teams. In addition, MEng finalists act as mentors to second year groups. At the start of the scheme, students visit their company and projects are negotiated and defined. For final year projects, there is also a major exhibition of all the work to which the companies and external examiners are invited. The scheme is directed by one member of academic staff, with the part-time support of one member of administrative staff. They receive the full backing of the Head of School. The companies pay a small fee to the University which funds the necessary industrial visits, hospitality, basic project costs and maintains a high report presentation standard.

4.0 EXPERIENCE-LED COMPONENTS OF ENGINEERING DEGREES
The case studies described above clearly demonstrate that the successful delivery of experience-led components within engineering degrees depends on a strong tripartite relationship between staffs; students and industry (Fig. 1). The three way interactions impact directly on both teaching and curriculum development. These relationships work in unique ways within each university and the case studies reveal resulting variations in the scale and impact of the experience-led activities on offer.
Fig. 1: Relationships between academic staff, students and industry for experience-led Engineering degree programmes

The results of the analysis of the case studies are summarised in Fig. 2. The main finding is that the case studies provide substantial evidence that experience-led engineering degrees help to meet the graduate recruitment needs of industry through providing attractive courses, relevant high quality curricula and student experience of industry. One very specific issue that needs to be addressed is the apparent decline in the number of placements available to Students.

Fig. 2: Findings from the case study analysis

The case studies mainly focus on the benefits to students and universities, but engagement with academia can also provide real benefits for industry which need to be disseminated more widely to encourage greater industrial involvement. A few examples from the case studies include:
• Placements acting as a cost effective recruitment tool for industry
• Employers of work-based students adopting technologies that their employees learn in
• the course of their studies
• Industry-sponsored prizes acting as a marketing tool for industry
• Professional development opportunities, particularly for junior engineers
• Industry-focused projects solving real problems for industry
• Universities helping industry to address skills shortages.

A significant barrier from the industrial perspective in engaging with academia is the cost involved (particularly staff time). It has been suggested that a scheme similar to the R&D Tax Credits could be possibly help alleviate this issue. From the universities’ perspective, establishing sustainable, effective working relationships between industry and academia is not without its problems. Developing a shared understanding is critical and requires overcoming differences in culture and language, taking time, effort and commitment. Communication needs to be two-way and not only do universities need to understand the priorities and drivers of industry, but industry needs to adapt to strategic and operational drivers of academia and have an appreciation of the needs of the new graduates that they recruit. It can be easier to establish engagement with large companies than smaller ones.

5.0 CONCLUSION
Indeed Engineering Departments in Africa Universities should learn from the Eastern Europe/Soviet University system as well as English University form of educational Training of engineers and take the benefit of all. Industrially relevant course content and opportunities for students to gain work experience should be an integral within every undergraduate engineering programme and therefore more widespread adoption of experience-led engineering of graduating engineering students must be the ultimate target of the Universities.

Sustainable world-class experience-led HE engineering degree programmes which attract the best students are an essential element to meet the graduate recruitment needs of industry.

To achieve this will require input from academia, industry, professional bodies and the government.

6.0 RECOMMENDATIONS
Recommendations arising from these research findings should be propagated by the Fellow of Academy of Engineering in ensuring commitments to supporting industry, professional bodies, university engineering departments and
government in implementing the recommendations and to disseminating the effective practice highlighted in this paper.

Experience counts and relevance motivates. Experience-led components must be embedded into every engineering degree, using the effective practice outlined in these case studies as inspiration. Experience-led engineering degrees benefit students and industry alike, supporting economic recovery and future prosperity.

 Preferential ring-fenced investment in experience-led HE engineering is required to deliver the higher skills needed. Innovative mechanisms are needed to focus and prioritise the investment required, in the context of a difficult fiscal period and an existing shortfall in the funding of engineering degree programmes necessary for financial sustainability.

Significant time and energy should be directed towards building, enhancing and sustaining university/industry partnerships. Effective partnerships are a key feature of the most successful exemplars.

REFERENCES


CLOSING THE ENGINEERING SKILLS GAP THROUGH PARTNERSHIPS BETWEEN SETAs AND UNIVERSITIES: A CASE STUDY IN THE EASTERN CAPE, SOUTH AFRICA

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ABSTRACT
This paper presents the work on the development of an engaged model to close the engineering skills gap in the Eastern Cape Province, South Africa, and bridge the challenges faced in higher education. It describes a structured approach through education providers and government to promote engineering as a career and provide communities with access to higher education. In South Africa, the success rate of school leavers and learners at Further Education and Training colleges (FET), and more specifically, the graduation rate of students at universities, is very low. Learners find it difficult to meet the standards set by higher education institutions. As an institution of higher learning, Nelson Mandela Metropolitan University (NMMU) is perfectly positioned to use its amenities, skills, and academic knowledge to support communities. This paper reports on a particular case study pertaining to an on-going endeavour in the Faculty of Engineering, the Built Environment and Information Technology at NMMU. It reports on the successful establishment of the merSETA (Manufacturing, Engineering and Related Services Sector Education and Training Authority) Chair in Engineering Development, with a focus on secondary schools, teachers in technical schools, FET colleges, and the promotion of women in the field of engineering. As this is the first chair of its kind in South Africa, the impact of this chair in the Eastern Cape Province, South Africa is discussed, as well as the model for implementing this chair. Data gathered by means of questionnaires and semi-structured interviews involving all the role players is analysed, so as to present a revised model for closing the engineering skills gap through partnerships between SETAs and universities for future implementation of similar projects.

Keywords: community engagement model; engineering; higher education; scarce skills.

RESUME
Le transfert de connaissances entre l’industrie et le milieu universitaire est une clé pour améliorer la formation et le développement de carrière et des compétences dans les deux secteurs. Ces derniers jouent un rôle essentiel dans le développement de l’économie du savoir et constituent un avantage concurrentiel durable. Des profils de compétences favorisent un apprentissage et un développement efficaces à partir de l’identification des comportements, des connaissances, des compétences et des capacités qui sont nécessaires pour l’exécution réussie d’un emploi ou d’une tâche. Par conséquent, l’industrie et le

Mots-clés: apprentissage et formation, carrière, compétences, programmes, esprit d’entreprise, création d’emplois.

1.0 BACKGROUND
Hall and Sandelands [2007] contend that engineering and construction skills shortages, a global phenomenon, are particularly acute in South Africa. They went on to suggest that solutions can emerge if the youth change their attitude towards the industry, and if innovative skills development initiatives are introduced by educators. However, Veldman et al. [2008], cite publications that indicate that learners in South Africa have the lowest scores for mathematics and science proficiency on the continent of Africa. According to Kraak [2005], this poor performance is reflected in the diminishing number of graduates that complete science- and mathematics-related degrees. Statistics of the 2011 National Senior Certificate (NSC) pass rates for Mathematics and Physical Science in the Eastern Cape were obtained and summarised. An alarming indicator is the percentage of learners that received marks of less than 50 per cent for Mathematics and Science. It is clear from Fig. 1 that 85.7 per cent of learners (22,602/26,359) achieved results of less than 50 per cent for Science and, as
illustrated in Fig. 2, an astounding 89.1 per cent of learners (33,908/38,058) achieved less than 50 per cent for Mathematics.

Apart from empirical reports, various studies have been undertaken by government departments and higher education institutions to determine the effects of critically scarce engineering skills. The literature shows that such shortages can slow the growth of an economy, among other problems [2007]. Hence, the training of learners in engineering is a national priority in South Africa [2007]. Based on this premise, this paper presents a specific case study that documents the use of the community engagement model to address reported gaps in engineering education. It focuses on the successful establishment of the merSETA Chair in Engineering Development at Nelson Mandela Metropolitan University. As this is the first chair of its kind in South Africa, the impact of this
chair in the Eastern Cape Province, particularly in communities and schools, and the implementation model form the nexus of the discourse.

**2.0 COMMUNITY ENGAGEMENT IN ENGINEERING EDUCATION**

‘Community’ is a term used to define groups of people and may be a geographic location, a community of similar interest, or a community of affiliation or identity [2008]. Community engagement creates the demand to share development issues and projects with government, industries, and others [2007]. In other words, community engagement may be able to ensure that the needs of people that specific projects are directed towards are met, because community input has been found to improve the final outcome [2011]. Community engagement is a planned process, with the specific purpose of working with identified groups of people so as to address issues affecting their wellbeing [2008]. For instance, Gossage [2011] discovered that students who were engaged in community-based projects had a more positive attitude towards developments in their community. Thus, Akbar and Rasul [2011] are of the opinion that the key principles of community engagement include the acquisition and use of local knowledge, commitment, integrity, collaboration, inclusiveness, equity, effective communication, and trust building.

The usefulness of the community engagement model is not limited to less privileged environments, as its relevance to studies in science, technology, engineering, and mathematics (STEM) disciplines cannot be overemphasised. Paterson [2011] noted that community engagement in engineering education assists in the evolution of a new order when disruptors shake the status quo and innovators connect with new values. In terms of the end product, Harkavy [2005] notes that a successful partnership should strive to make a positive difference by contributing to the wellbeing of people in the community, which could, in turn, improve the quality of life and learning within the higher education institution. In brief, the goals of community engagement are to develop trust, solicit new resources and associates, produce better communication, and improve overall project outcomes [2006]. The positive impact that community engagement has made in the recent past includes the fact that academic partners can gain enhanced understanding of the issue under study and an appreciation of the role and value of community involvement. In addition, new insights into the relevance of a project, and the various benefits to be gained from it, can lead to increased opportunities to disseminate the findings of the project. The latter point is exactly the objective of this research paper, where data gathered by means of questionnaires and semi-structured interviews involving all the role players was analysed, so as to present an engagement model for closing the engineering skills gap through partnerships between SETAs and universities for the future implementation of similar projects in South Africa.
3.0 GAPS IN ENGINEERING EDUCATION IN SOUTH AFRICA

South Africa has a critical shortage of people with technological training. Increasing the number of technologically trained people, both men and women, is thus essential for economic development. The South African government has identified as a national priority the need for an increase in the number of graduates trained in the fields of science, engineering, and technology (SET). To ensure a growing and sustainable economy, South Africa must have a competitive manufacturing industry. It is therefore of national interest to implement a range of interventions to improve the access of learners to the School of Engineering at NMMU, as it is a key player in the provision of adequate and well-skilled engineering human resources nationally, and particularly in the Eastern Cape. Furthermore, it is imperative that human resource diversity in science, engineering, and technology is developed to its fullest to ensure the optimum utilisation and development of the human resources of our nation [2011]. In November 2009 the Department of Higher Education and Training (DHET) assumed responsibility for the Skills Development and Training Sector in government. This provides the opportunity for the creation of a coherent and separate post-school education and training system. The Minister of HET, Mr Blade Nzimande, has identified one such challenge as being to “improve coordination between the SETA system and education and training institutions, particularly FET colleges and universities of technology”. The Faculty of Engineering, the Built Environment and Information Technology at NMMU, a comprehensive university, is ideally positioned to take on this challenge with merSETA, as the majority of the programme offerings are similar to those offered by universities of technology [2011].

The challenge facing engineering educators in South Africa in developing students to the point where they can function effectively in a world characterised by complexity is daunting [2010]. Phogole [2008] relates the challenges faced in their education and careers, particularly in STEM disciplines, by people that have had a rural upbringing. This suggests that although mandatory apartheid education in South Africa officially ended in the early 1990s, the effects of unequal education provision are still being felt throughout the country [2008]. It can therefore be argued that many students intending to study engineering at higher education institutions may not be adequately prepared for what is expected of them, since several problems still plague many secondary schools [2010]. The challenge for universities is therefore to find means of effectively teaching a more diverse student body and improving the graduation rate of previously disadvantaged students. As a case in point, the graduation rate in engineering programmes at a reputable university in South Africa indicates that close to half of the students admitted between 1994 and 2003 dropped out during the programme [2006]. The dropouts are students that failed to complete their studies.
successfully and graduate with an engineering degree. Interventions to address the under-preparedness of prospective students and multi-pronged academic support are required to improve the throughput rate of engineering graduates in South Africa.

4.0 THE MERSETA CHAIR IN ENGINEERING DEVELOPMENT (ED) AT NMMU

The establishment of the merSETA Chair in Engineering Development at NMMU in 2010 has been used as the vehicle to address some of the concerns raised above through various projects. The proposed structure and focus of the merSETA Chair in Engineering Development is illustrated in Fig. 3 [2009].

![Diagram of the merSETA Chair in Engineering Development](image)

Fig. 3: The structure and focus of the merSETA Chair in Engineering Development

The four primary objectives of the merSETA Chair in Engineering Development at NMMU are [2011]:

- to create an awareness of the relevance and importance of science, engineering, and technology (SET) in our rural communities, and to promote SET among learners at rural schools;
- to develop a support programme for FET colleges, so as to increase capacity in engineering at these colleges and strengthen the collaborative links with NMMU;
- to increase the capacity of educators at technical high schools in the Eastern Cape; and
- establish a Women in Engineering unit at NMMU to promote and monitor the development of women in the fields of SET in the Eastern Cape and at NMMU.
The geographical area of the first phase of the chair was confined to the eastern half of the Eastern Cape up to and including East London. The project covered three district municipalities, namely Nelson Mandela Bay Metropolitan Municipality, Cacadu District Municipality, and Amathole District Municipality. In 2010, NMMU gained the prestigious status of becoming an Institute of Sectorial or Occupational Excellence (ISOE), accredited by merSETA, which aligns the university strategically to access additional resources to implement critical projects. This accreditation has seen the introduction of two very successful programmes in the Eastern Cape, namely: The Maths, Science and Engineering Development Programme (MSEDP) in the rural areas of the Somerset East district (Cacadu Municipality); and an internship programme at the Port Elizabeth College in Port Elizabeth.

The model of the chair was revised in Phase Two in 2011, which involved a revision of the objectives and a redefinition of the scope of the chair. The business plan for 2011 consolidates the seven projects of 2010 into four major categories. The various projects are illustrated in Fig. 4 [2011].

![Diagram showing the projects identified in Phase Two of the merSETA Chair in Engineering Development](image-url)

**Fig 4: Projects identified in Phase Two of the merSETA Chair in Engineering Development**

### 5.0 RESEARCH METHODOLOGY

For the purposes of this article, the various projects were researched and reported on, as illustrated in Figure 4. In this study, results of the implementation of a merSETA Chair in Engineering Development at NMMU are illustrated through the structure of the intervention and the impact the programme had on specific individuals. The requirements of High Schools and Colleges were identified through the completion of a needs analysis and interviews.
According to Yin, cited in Viral [1997], interviews are one of the most important sources of case study information. In this study, semi-structured interviews were conducted with the following groups namely, staff members at Port Elizabeth FET College; educators at four technical high schools in Port Elizabeth; Department of Basic Education officials, teachers, and other role players involved in the interventions at selected schools to upgrade and up-skill mathematics and science learners; and senior officials at merSETA. Yin, cited in Viral [1997], recommends that a chain of evidence be maintained to increase the validity of case studies. A revised engagement model is graphically represented at the end of the article.

6.0 RESULTS OF INTERVENTIONS OF THE MERSETA CHAIR IN ENGINEERING DEVELOPMENT

The initiation and implementation of the structured intervention between the merSETA, the NMMU and external stakeholders was initiated and managed through the establishment of the appropriate human resource capacity, the identification of objectives and the documentation of accomplishments.

6.1 Establishment of Human Resource Capacity

The establishment of sound human resource capacity at NMMU was the first order of business at the commencement of the merSETA Chair in Engineering Development (ED). Fig. 5 illustrates the original human resource hierarchy based on the first business plan that was implemented.

![Fig 5: merSETA Chair in ED Human Resource Hierarchy](image-url)
This activity plays a vital role in achieving the deliverables as set out in the business plans of the merSETA. Another key activity is the identification of motivated individuals at partner institutions and units that have a vested interest in the successful implementation of the business plan.

6.2 Summary of Results of merSETA Intervention

The impact of the merSETA Chair in Engineering Development is summarised in this section in line with the structure of phase two of the implementation plan.

6.2.1 Project A: High School Intervention

The objectives of the high school intervention project included (i) to increase capacity of educators and infrastructure at technical high schools in the Eastern Cape Province, (ii) to promote Engineering as a career amongst high school learners, and (iii) to assist in the development of laboratories at technical high schools. Technical high school teachers are confronted with new technologies and curricula and need to stay abreast with these developments. Failure to do so may lead to poor pass rates, de-motivation of the learners and frustrated teachers. The Chair strives to develop and present development courses and programmes to teaching staff at technical high schools, especially in the field of technical subjects. The outcomes of activities of the high school intervention project are indicated in table 1.

Table 1: Activities of High School Intervention

<table>
<thead>
<tr>
<th>Activity</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Educator Training</td>
<td>Provide engineering training in AutoCAD, Inventor, Advanced AutoCAD and PLC Programming to 33 educators.</td>
</tr>
<tr>
<td>2 Educator Career Guidance</td>
<td>Provide Engineering Career Guidance workshops to 107 Educators. Develop a career guidance poster for engineering learners.</td>
</tr>
<tr>
<td>3 Maths and Science Educator Development</td>
<td>Provide mathematics and science development programme to 110 educators in rural district of Eastern Cape.</td>
</tr>
<tr>
<td>4 Engineering awareness workshops to learners (rural schools)</td>
<td>Provide engineering awareness workshops to 1118 learners from rural high schools in the Eastern Cape.</td>
</tr>
<tr>
<td>5 Engineering awareness workshops to learners (Port Elizabeth Metro)</td>
<td>Provide engineering awareness workshops to 61 learners from technical high schools in Port Elizabeth.</td>
</tr>
<tr>
<td>6 Junior Cyber Junkyard Competition</td>
<td>Introduce automation competition to technical high schools and provide training to 28 learners and 7 educators. Provide automation hardware to seven high schools in conjunction with Siemens SA.</td>
</tr>
<tr>
<td>Introduce an engineering</td>
<td>Provide a 1 week engineering winter school to 57</td>
</tr>
</tbody>
</table>
winter school | learners from rural schools
--- | ---
8 | Maths and science development for grade 11 and 12 learners in rural areas of EC. Provide a maths and science development programme programme to 194 learners from rural schools in the EC.
9 | Laboratory development | Develop or maintain three laboratories at technical high schools (Technical drawing upgrade at Kwezo Lomzo THS, maintenance infrastructure at Bethelsdorp THS, implementation of PLC training laboratory at Port Rex THS).
10 | Engineering bursaries to learners | Provide full academic engineering bursaries to 10 learners from rural high schools.

6.2.2 Project B: FET College Intervention

The objectives of the FET college intervention project are (i) to develop support for FET colleges (FETC) in order to increase capacity in Mechanical Engineering, Industrial Engineering and Mechatronics and (ii) to strengthen the collaborative links between NMMU and these FETCs. A key up-skilling strategy that will be introduced to FET colleges includes the teaching training in methodologies and assessment skills; practical training interventions to up-skill educators in their chosen specialisation in order for them to impart and transfer practical skills to the learners; up-skilling theoretical training interventions for educators in their specialist areas; and exposure to the latest or cutting edge technology. The outcomes of the activities of FET college intervention project are indicated in table 2.

Table 2: Activities of FET College Intervention

<table>
<thead>
<tr>
<th>Activity</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Educator Training</td>
<td>Provide engineering training in Pneumatic Control Systems, Siemens LOGO, Siemens PLC Programming, Advanced AutoCAD and CNC Lathe Programming to 46 educators</td>
</tr>
<tr>
<td>2 Junior Cyber Junkyard Competition</td>
<td>Introduce automation competition to three technical colleges and train 12 students and three educators. Provide automation hardware to three technical colleges in conjunction with Siemens SA.</td>
</tr>
<tr>
<td>3 Lecturer Development</td>
<td>Create capacity to two educators to continue with higher qualifications.</td>
</tr>
<tr>
<td>4 Laboratory Development</td>
<td>Develop two laboratories at two technical colleges (Fanuc robot training cell at PE College and Switchgear training laboratory at EC Midlands College).</td>
</tr>
<tr>
<td>5 Internship programme</td>
<td>Implement an internship for PE College, which includes the placement of two senior students from NMMU for three months at the mentioned college.</td>
</tr>
</tbody>
</table>
6.2.3 Project C: Woman in Engineering

The objectives of the Women in Engineering project include, inter alia, (i) to promote and monitor the development of women in engineering at NMMU; (ii) to accelerate the increase of female student numbers in engineering; (iii) to support holistic development of female students in engineering; (iv) to build a learner-centred environment for female students in engineering; (v) to establish a learning community for female students in engineering; and (vi) to “grow future academics”. The South African government identified the need for an increase in the number of women in engineering as a national priority. Girls should be encouraged to take science subjects at schools, not only to pursue a scientific, engineering or technological career, but also to be able to apply scientific concepts in their daily lives. The outcomes of activities of the Women in engineering intervention project are indicated in table 3.

Table 3: Activities of Woman in Engineering Intervention

<table>
<thead>
<tr>
<th>Activity</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Create a support unit to female engineering students at NMMU</td>
</tr>
<tr>
<td>2</td>
<td>Support to female students</td>
</tr>
<tr>
<td>3</td>
<td>Portfolio development</td>
</tr>
<tr>
<td>4</td>
<td>Development of female engineering students</td>
</tr>
<tr>
<td>5</td>
<td>Community Engagement</td>
</tr>
<tr>
<td>6</td>
<td>Bursaries to female students</td>
</tr>
<tr>
<td>7</td>
<td>Marketing material</td>
</tr>
<tr>
<td>8</td>
<td>Woman in Engineering seminars</td>
</tr>
</tbody>
</table>

6.2.4 Project D: Skills Development

The objectives of the skills development project include (i) short learning programmes to be developed and presented to industry; (ii) an energy management system through utilisation of renewable energy; (iii) the design and commission of a renewable energy storage unit; (iv) the manufacturing of an electric formula student racing vehicle; and (v) the design of a four-wheel solar vehicle in collaboration with the automotive industry. The manufacturing industry both nationally and globally has become very competitive. In order to
succeed in such a competitive environment it is imperative that all human resources are operating at the required technological skills level. The outcomes of activities of the skills development intervention project are indicated in table 4.

Table 4: Activities of Skills Development Intervention

<table>
<thead>
<tr>
<th>Activity</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Short learning programme for industry</td>
<td>Develop an industrial data communications short learning programme for VWSA (LIN and CAN bus systems)</td>
</tr>
<tr>
<td>2 Renewable energy management system</td>
<td>A renewable energy software management system and website developed; a solar tracking system for solar panel system manufactured;</td>
</tr>
<tr>
<td>3 Renewable energy storage system</td>
<td>Design and manufacture a thermal energy storage unit for industry process heating (Masters and B Tech students)</td>
</tr>
<tr>
<td>4 Electric formula student race vehicle</td>
<td>Complete the design and manufacture of an electric single-seated formula student race vehicle (under- and post-grad students).</td>
</tr>
<tr>
<td>5 Solar vehicle</td>
<td>Complete the design and manufacture of a solar vehicle.</td>
</tr>
<tr>
<td>6 Process controlled water tank system</td>
<td>Design and manufacture a process control unit to be utilised in both student (academic programmes) and industry training programmes</td>
</tr>
<tr>
<td>7 Renewable energy workshop for Engineering students</td>
<td>Provide a renewable energy workshop for 33 engineering students at NMMU.</td>
</tr>
</tbody>
</table>

6.2.5 General Outcomes of the merSETA Chair in Engineering Development

Various achievements have been realised during the period of 2010 - 2012 in the merSETA Chair in ED. A total of five laboratories were developed, two at a FET college and three at technical high schools. Programmable Logic Control (PLC) technology was implemented at seven high schools through the introduction of the Siemens Cyber Junkyard competition. The various projects that were implemented benefited a large number of students, educators and high school learners. The number of individuals are summarised in Fig. 6.
In addition to Fig. 6, a total of 1458 learners from various high schools (including rural schools) benefited from the merSETA Chair in ED through programmes such as (i) the mathematics and science development for grade 11 and 12 learners; (ii) engineering and career guidance workshops promoting engineering; and (iii) technical training seminars in automation. As was mentioned, the needs of high schools and colleges were determined by conducting a needs analysis through interviews and workshops with educators and lecturers. The major issues were documented, executed and financial plans were determined. Following from the interventions of the Chair, the following major challenges facing technical high schools and FET colleges were identified:

- Capital budgets to acquire latest technologies at high schools and maintaining current infrastructure and equipment which are aging and in most cases not maintained at all;
- The continual change of the academic landscape and the excessive administrative burden on educators;
- No formal degrees or diplomas exist for technical educators in the Eastern Cape. The average age of technical educators is alarmingly high and the qualification of educators must be addressed;
- Morale of educators is muted and significantly influences the ability to effect technological change from external stakeholders; and
- Shortage of skilled technical assistance in laboratories at FET colleges as well as the ‘over-teaching’ of lecturers.

The merSETA Chair in ED activities at the NMMU also had a positive influence on achieving the academic goals of executive management. The NMMU is a
university that promotes research and engagement [2013] and the merSETA Chair in ED initiative reinforced the vision of NMMU through (i) increased research outputs – Masters and doctoral graduates, publications, patents; (ii) growing the next generation of academics; (iii) research sustainability - diversified funding sources; (iv) strategic partnerships; (v) the integration of internationalisation; and (vi) contributions to improved socio-economic conditions.

7.0 REVISED ENGAGEMENT MODEL FOR PROJECTS OF THIS NATURE
Projects of a similar nature at NMMU were integrated to ensure a more effective utilisation of resources, which will ultimately lead to greater impact and the achievement of set goals and objectives. Fig. 7 illustrates the integration of the merSETA Chair in Engineering Development projects with the AIDC’s TEI HRD Programme (Automotive Industry Development Centre’s Tertiary Education Institutions Human Resource Development), the Govan Mbeki Maths Development Unit, the STEM Laboratory, the Wind Energy Research Group (WERG), as well as the VWSA/DAAD International Chair in Automotive Engineering.

Fig. 7: Integration of merSETA with existing NMMU Programmes

Working within a framework established by the merSETA, there is a growing commitment to create an institutional culture that promotes collaboration, equity, accountability, and cultural competency to improve the impact of the Chair’s activities within the programme. The key steps to the engagement strategy are (i) to identify the key deliverables as negotiated with the major sponsor, in this case merSETA, that will benefit the relevant beneficiaries; (ii) to identify a key motivated individual at each of the institutes that can benefit from the
programme; (iii) to measure one’s engagement in actions and identify deadlines for deliverables and conduct regular management meeting to measure progress; and (iv) to keep accurate proof of all deliverables.

Fig. 8 graphically illustrates the revised model that is followed to successfully implement and sustain an intervention as discussed in this paper.

![Revised Engagement Model for the merSETA Chair in Engineering Development](image)

**Fig. 8: Revised Engagement Model for the merSETA Chair in Engineering Development**

### 8.0 CONCLUSION

In conclusion, the success of this project is underlined by a sound business plan, which includes (i) the terms of reference, which describe the purpose and structure of the programme; (ii) a well-defined project identification and statement of key deliverables and (iii) clear declarations of responsibilities of all stakeholders. The authors have identified the following key factors of success in establishing an intervention of this nature:

- Identify a partner university that has sound financial and strategic policies that govern engagement.
- Identify a motivated person at the partner university to drive the expressed business plan.
- Identify key stakeholders in the business plan (colleges, high schools, learners, students, units).
- Establish association with stakeholders in business plan.
- Establish a relationship with a dedicated and motivated individual from each of the stakeholders.
- Determine the need requirements of stakeholders through a needs analysis (NA).
- Define the needs clearly and corroborate with stakeholders.
- Resolve identified needs effectively and professionally.
Although, funding and physical infrastructure are always the underpinning requisites for implementing and sustaining an intervention of this nature, it was found that without the appropriate human resource apportionment, this intervention had no prospect of success. The dedication and willingness of individuals to achieve success are crucial in achieving the various objectives set. These individuals do not only include the strategic managers and stakeholders of the programme, but more so, the individuals that are responsible for realising the set goals. One of the major challenges with external stakeholders (teachers and FET college lectures), is the time that these individuals have available for interventions. Co-ordination of added training schedules, learner interventions and laboratory development has to be carefully scheduled so as not to intervene with academic rosters of learners.

Finally, it is evident from the results recorded in this paper, that the merSETA Chair in Engineering Development at NMMU, through the engaged model, contributed to closing the engineering skills gap in the Eastern Cape Province, South Africa, and bridging the challenges faced in higher education, including promoting engineering as a career and providing communities with access to higher education.

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ACHIEVING HIGHLY EFFECTIVE PERSONALIZED LEARNING THROUGH LEARNING OBJECTS

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ABSTRACT
A personalised learning system is one in which the information delivered to learners is customised to fit their personal or environmental preferences. Despite the existence of some evidence of the value of personalised learning, there is, to date no widely used personalised learning systems. This paper argues that the primary reason is because of the absence of repositories with the requisite properties. The paper presents the four conditions that any system used for personalised learning delivery would need to have for it to be effective. The paper then describes the architectural features that such a system must also have.

Keywords: Learning Object, Learning Style, Open Education Resources, Personalised Learning

RESUME
Un système d'apprentissage personnalisé est celui dans lequel l'information délivrée aux apprenants est personnalisée pour répondre à leurs préférences personnelles ou environnementales. Malgré l'existence d'une preuve de la valeur de l'apprentissage personnalisé, il n'existe pas à ce jour de système d'apprentissage personnalisé largement utilisé. Cet article soutient que la principale cause est l'absence de référentiels contenant les propriétés requises. L'article présente alors les quatre conditions dont tout système utilisé pour la fourniture d'apprentissage personnalisé aurait besoin pour être efficace. Il décrit ensuite les caractéristiques architecturales qu'un tel système doit également avoir.

Mots-clés: objets d'apprentissage, styles d'apprentissage, ressources éducatives libres, apprentissage personnalisé.

1.0 INTRODUCTION
A learning object (LO) has been defined by the IEEE Learning Technology Standards Committee as "any entity, digital or non-digital, which can be used, re-used and referenced during technology supported learning" (2009). LOs are usually reusable digital multimedia or text-based materials accessed through a
computer or telephony network [2009]. To enable reuse of LOs, they are usually associated with metadata, which are small amounts of data containing information about the attributes of the learning objects. Although e-learning systems have existed long before the formulation of the term “learning object”, the new emphasis on reusability in implementing e-learning systems has led to a greater focus on proper classification and formalised development paradigms. The renewed formalisation, combined with the emergence of initiatives to open up the process of LO development and delivery can allow the successful implementation of something considered to be a holy grail of sorts in some areas (for example see [2006]) of educational psychology: Personalised Learning (PL).

This paper posits that the major cause of the failure of current personalised learning systems to impress so far is the absence of an important ingredient: large enough LO repositories that meets criteria which shall be described later. We argue that the increasing popularity of LO-driven Open Education Resources (OERs) offers a tremendous opportunity to put the required repositories in place for effective PL systems.

2.0 OVERVIEW OF LEARNING STYLES AND PERSONALISED LEARNING

A personalised learning system is one in which the information delivered to learners is customised to fit their personal or environmental preferences. In the last few decades, theories and models have been advanced to study and analyse character and cognitive traits possessed or exhibited by students. Such models as a class are referred to as Learning Style Theories (LSTs) in this paper.

As shown in fig. 1, a personalised education delivery system must have a repository of learning objects and a layer to match students’ traits to appropriate sub-domains of that repository. For a PL system to be effective, appropriate content must be available for any arbitrary number of students with an arbitrary numbers of unique trait parameters, topics of interest, and level of previous knowledge of the subject matter. This of course implies a courseware repository that can provide an essentially infinite quantity and diversity of educational contents. No such repository exists at present. The world-wide web (WWW), the largest and most obvious candidate for a close facsimile, is difficult to use because of its improperly indexed, heterogeneous structure.
Some work has been done on applying learning style schemes (1972, 1971 and 1984). In their study based on administering Kolb’s LSQ and Sternberg’s MSG to 210 college students, (2000) found some correlation between thinking/learning styles and academic performance. Reference (1995) found that when attention was paid to student's learning styles; improvements could be seen in their attitude, thinking skills and academic achievement. (2000) reported that learning style correlated strongly with academic self-efficacy and locus of control while (2003) concluded that when hypertext architectures are matched to student’s cognitive styles, learning is more effective. Although other studies have found only weak evidence in support (for example 1999), a majority of educators seem to have accepted the idea of improved knowledge transfer when some trait of the student is matched to some trait of the instructor or property of the knowledge delivery medium.

This acceptance has in turn given rise to the notion of personalised learning. The basis of the concept is that an ideal educational system should have a layer between the knowledge source and the student, whose primary task would be to consider the characteristics or traits of the student in extracting the relevant information from the source (fig. 1). In this vein, a number of PL systems have been developed. For example, (1996)-(2003), and a whole class of research on
Intelligent Tutoring Systems (ITS) describe various implementations of PL systems. While most of these systems are reported to be effective to varying levels, one fact is immediately apparent: PL systems are being used only in the context of research, with no large scale deployments that would be a sign of general acceptance of the idea among the generality of instructors. This poor adoption of PL systems is primarily due to the absence of the required type of LO repositories.

3.0 THE SOURCE-SELECTOR-LEARNER MODEL FOR PERSONALISED LEARNING

The learning process is fundamentally a transfer from an information source to the student. LST-related researches discussed in section II suggest also that there is maximum knowledge transfer when some characteristic of the knowledge source is matched to the characteristics or traits of the learner (the sink). This inspires a comparison to the concept of impedance-matching for maximum power transfer in Electrical Engineering. In addition, in the course of studying, a student often needs to select one of a number of available information sources, a process associated with a delay and thus analogous to the channel selecting operation of a multiplexer. Based on the forgoing, our model of personalised learning is referred to as the Source-Selector-Learner (SSL) model, and is depicted graphically in fig. 2.

While the graphical representation of the SSL model draws from Electrical Engineering, there is little doubt that the process being depicted itself is information retrieval. In fact, since the central activity of the student in the SSL model (selection) is associated with a switching from one relevant information source to another, the topic of Relevance in Information Retrieval (IR) is central to the SSL model.

There has been a fundamental shift in the understanding and evaluation of the concept of topical relevance in the last few decades. In the beginning, relevance was commonly treated as a quantity that a document retrieved from a system possesses. This view depicts relevance as a property of the internal mechanism of the system that is the result of a match between a user’s query and the index terms assigned to documents in an IR system. Such a view of relevance is however incomplete, especially since it is not the system but the user who ultimately has to determine how relevant the document is to his needs (1966).
Thus, a new view of relevance has developed to reflect the user’s importance in determining relevance. This emergent view of relevance from the user’s perspective is all too subjective and comparative; in fact, a document that a user considers very relevant to a query in one context may not be so relevant to the same user in a different context. One characteristic of relevance defined in this way is that it is a multi-component quantity.

Using the N-variable concept of relevance judgment (1967), (1994), the relevance of retrieved information from the user’s perspective can be seen as a vector in N-dimensional space. For example, using Schamber’s framework, the relevance of a particular LO, \( D \) to a student’s information needs \( N \) (based on his relevance judgment) can be conceptualised as an 80-dimensional vector. For an N-dimensional relevance framework with dimensions’ magnitudes normalised (such that the maximum magnitude any dimension can have is unity) an extremely relevant document would have dimensional magnitudes of approximately unity on most dimensions. A completely irrelevant document would have zero or near-zero magnitudes on most dimensions. This notion of relevance judgment mirrors the vector state approach that has been used in IR for half a century, and can benefit from the huge amount of research that has been done on that topic, in particular, the obvious question of how to assign numeric values to relevance framework dimensions.

Student and instructor traits are represented in the SSL model as impedances ("Z"). The view of traits as impedances is justifiable because just as impedances are responsible for energy dissipation and losses in an electrical system, student and instructor traits can be seen as peculiarities that lead to some loss in transit in
the knowledge being transmitted when they are not matched. The idea of optimum knowledge transfer when the impedance of source and sink are matched also follows from this representation. To reflect the multi-component view of relevance, the impedances in the SSL framework are M-dimensional entities, which each dimension representing a particular trait of interest:

\[ Z = Z_1i + Z_2j + Z_3k + Z_4l + Z_m + \ldots \]

A PL system would be expected to be more effective if its approximation of source and learner impedances utilises more dimensions. That is, the more the number of traits used in determining appropriateness of learning objects to student, the better. For example, a PL system that tries to personalise information supplied to students by using their prior knowledge, study objective, browsing history, social interaction, instructional preference and cognitive personality should perform better than one that uses just information processing. However, using an excessively ‘accurate’ approximation (with too many dimensions) could result in over-personalisation which invalidates learning (2004).

The instructor is an individual who authors or reformulates a learning object available for use in an e-learning system. Learning is personalized if a mechanism exists by which information whose traits or impedance matches the traits (or impedance) of the learner to some measure of satisfaction, can be found within a repository within some specified performance-related time limit. In the SSL model, a learning object is the minimum unit of information. It contains an arbitrarily small amount of information, all of which has approximately the same coordinates in an N-dimensional relevance or relevance judgment framework. A learning object could therefore be a section, a paragraph or a whole book so long as its entire contents share same coordinates in an N-dimensional relevance space. A source is an entity that contains multiple learning objects, within a common physical boundary such that the same search strategy and mechanisms can be used to access any random document within the boundary. A repository is a network-accessible storage system in which learning objects may be stored for possible future access or retrieval. A repository usually implements mechanisms by which digital objects can be deposited or accessed (2006).

When a student switches from one source to another, she must necessarily identify a document in the new source that is relevant to her needs. The switching time, \( T_S \) is the time it takes for the student to move from one relevant document to another relevant document either within or outside the same source.
4.0 HOW LEARNING OBJECTS USED WITHIN OERs CAN FACILITATE PERSONALISED LEARNING

The present resurgence in e-learning has coincided with the departure from an original for-profit basis [2001] to a more commercially flexible model. Leading the charge in the new open paradigm are e-learning platforms called Open Education Resources (OERs). OERs are “teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others” (2009). Although implementation specifics vary from institution to institution, the general inspiration behind the OER movement is consistent: to make a large range and quantity of educational materials freely available online. While an overwhelming amount of information has been freely available on the WWW for at least two decades now, the feature that distinguishes OERs from other online information sources is that OERs are provided within frameworks that target formal educational curricula, and with some level of control on the quality and appropriateness of the materials to said curricula. There are an ever-increasing number of OER projects, with the Massachusetts Institute of technology Open Courseware (OCW) widely viewed as the largest.

The requirement that a PL system must have a high level of style diversity places some constraints on how they can be implemented. These constraints have two facets. First, to ensure that as many users with diverse styles and contexts as possible can find the PL system useful, a repository of essentially infinite size is required. It is extremely difficult for a single institution to have the resources to generate the required repository size. A repository to which a large group of individuals can contribute would be the only way to guaranteeing the requisite size. In addition, the requirement for style diversity requires that many individual contributors involved. This is the only way to guarantee that the contributed materials will have genuinely distinct styles.

The above constraints point to the importance of OERs. Most OERs are implemented as community-based systems where contributors can be spread over a very large physical area, increasing the likelihood of style diversity. The communities are also usually open, meaning that the number of contributors could become large enough to generate the requisite repository sizes.

5.0 CONDITIONS REQUIRED FOR SUCCESSFUL IMPLEMENTATION OF PERSONALISED LEARNING SYSTEMS

In an effective PL system, any query should return multiple documents with the same level of topical relevance, but with variations in style and media. If the same query is entered by a number of students, different responses should be obtained by each. The greater the variety of styles of retrieved documents to a
query, the larger the number of students’ personality or learning style profiles that can be catered for. For instance, in a repository with Physics learning objects, there should be a wide range of documents and styles on Newton’s third law of motion, ranging from visualisation videos (which should vary in presentation and content style), to recorded classroom lectures, to presentation slides, or simple text (again with variations in style), worked examples, tutorial questions, assignments and remote or virtual laboratory exercises.

This means that the repository of an effective PL system must have a high level of topical duplication of a particular sort. We refer to this type of duplication as divergent-style topical duplication (DST duplication) because multiple documents with the same topical relevance must have different styles of presentation. Thus, a first condition that a PL system must meet is that its repository should have a considerable amount of DST duplication. Fig. 3 depicts the concept of DST duplication. A locus of points equidistant to the vertical would represent materials with approximately the same topical relevance to a user’s query, but with varying styles. Considering the fact that there are an essentially infinite number of student styles, such loci would tend towards infinite length for an ideal PL repository.

![Diagram of DST duplication](image)

**Fig 3:** Divergent-style topical duplication: learning objects returned from different sources within a repository to the same query have approximately the same topical relevance but diverse style-related relevance factors

DST duplication is easily achievable by any OER system with a sufficiently large number of contributors. For example, as more institutions join the MIT OCW consortium, an increasing number of them will start providing content that
overlap to significant extent. The MIT OCW site may have lecture notes and class assignments on, say, second order control systems. The Obafemi Awolowo University (Nigeria) OCW site may have simulations and lecture notes on the same topic, a Swedish university might have visualisation stills and presentation slides, while a Chinese university may have more of the same but with text in mandarin. Assuming the interface through which students interact with OCW sees the different sites as part of a seamless whole, then, as the number of OCW sites increase, the breadth of materials on second order control systems would increase, improving the chances that a student would get information that is matched to his style.

Duplication is usually considered a negative attribute for a system to possess. Indeed, many supporters of the OER movement regard the elimination of duplication of efforts and resources as one of its advantages (for example, see 2004). In vector space theory of relevance, which directly motivated our N-dimensional relevance judgment framework, duplication or synonymy is generally considered a problem (2002). However, while it is true that duplication is often counterproductive, DST duplication, as described in this section, is absolutely essential for PL systems. Therefore, while OERs proponents advocate the elimination of duplication in courseware production and deployment, it should be borne in mind that a high level of topic duplication along with style diversity is imperative if there is any interest in delivering personalised education.

A PL system must be able to match certain attributes of the source to traits of the student. This is why, as described above, the same query would yield different results depending on the student making the query. This in turn assumes that some means is put in place to collect information about student’s styles and ascribe traits to various available sources in the repository. Students’ profiles can be developed either by asking students to answer specific questions or by using software agents to monitor students’ usage of the repository and thereby build a profile. Neither the idea of developing student’s profiles nor that of augmenting queries with information derived from the profiles is unique. OER frameworks have the advantage that instruments for determining, storing and managing students’ profiles and learning object metadata can be defined from the ground up.

A PL system must also meet some time constraint in order to be useful. For reasons we have explained previously, we are adopting a 20-minute rule. That means that any material that is available in the repository must be available to the user within 20 minutes of the search task. The search engine and the matching module must be fast enough to allow this constraint to be met. As a repository
increases, the time needed to retrieve a random document from it increases. This is particularly noticeable on the World Wide Web, whose size and complexity makes it difficult to search. Achieving DST duplication calls for a repository with essentially unbounded growth. This would ordinarily mean it would be impossible to guarantee meeting the 20-minute rule.

However, in the presence of a very good indexing and search system, a repository can be made to behave like a traditional IR system irrespective of its size. One advantage that OER systems enjoy in this regard is that they are usually planned from the ground up. Unlike the World Wide Web which just grows without much structure or coordination, OER systems can have proper indexing systems and search engines that are built to perfectly match such systems. Based on the argument put forward earlier as to why OERs alone can meet the requirements for implementing successful PL systems, a fourth requirement is implied: PL systems can only be implemented by using platforms that share the features of the OER platforms of today.

7.0 OER ARCHITECTURE FEATURES TO IMPLEMENT PERSONALIZED LEARNING

Although, OER systems could be used to implement personalised learning if desired, not all of them can so function without modifications. For an OER system to be able to act as PL system, a number of architectural elements are called for as shown in fig. 4.

![Fig. 4: Suggested OER Architecture to Enable PL Delivery](image)

The suggested architecture has three categories of components: communities, tools and learning-related data. There are four human communities. The domain expert community is made up of instructors, researchers and individuals who help in the knowledge discovery or presentation process. While some members of this
community will be able to make use of development tools themselves, many will depend on the skills of another community: the developers.

Developers serve as an interface between domain experts and tools for content development. The community of students and users of the PL system is the third community, while the Reviewer/Assessors form perhaps the most important community. This community is responsible for assessing learning objects and populating LO metadata to reflect various attributes of the objects. Assessors would also be responsible for, from time to time, determining the best combinations of learning style theory to adopt for the OER framework. Assessors are also responsible for the important role of quality assurance, ensuring that some minimum level of quality is maintained by the system as a whole.

There are three learning-related databases at the heart of the architecture: the learning objects, associated metadata and records about the student’s preferences. Each of these three can be stored in a single database system or across a large geographical area. It is however crucial that irrespective of the actual storage system topology, all the tools in the OER architecture can interact with the data objects as a seamless whole.

Content development tools are important for an OER architecture, and even more so for one to be used for personalised learning. Such tools will be used by either the domain expert or developer communities to populate the learning object database. The metadata for the learning objects will be generated by the Assessor community by using another set of tools, while tools used by students for interacting with the system for a third class. Some scheme should also be incorporated by which students can play some role in tagging learning objects. By far the most important part of students’ tools is the search infrastructure which must not factor in data on student’s preferences from the students’ profiles database. A licensing layer is required because of concerns of how to manage Intellectual property issues. An OER system must include a layer to allow flexibility in instructors’ choice of licensing model.

The final architectural component is the interoperability logic. As mentioned earlier, the most important property for PL systems to have is DST duplication, which increases as repository size increases. This suggest, rightly, that if some means could be found to allow two different OER systems to interoperate such that together, they still meet the 20-minute rule, the level of DST duplication of the resulting system would be much higher. An interoperability layer is therefore important because it can allow an OER system work with another.
8.0 CONCLUSION
In this paper, we have argued that the primary reason why PL systems have been limited in effectiveness is the fact that there are no sufficiently large repositories with four attributes which we have determined to be essential for the achievement of proper PL. First, repositories for PL systems must have a high level of topical duplication (“DST duplication”) which requires very large database sizes. Secondly, such systems must have search infrastructure that allows them to meet some stated performance measure. In this regard, we have suggested a 20-minute rule: any PL repository must allow student retrieve information that is most relevant to his information needs within 20 minutes, as long as such information exists within the repository. PL repositories must also contain mechanisms to collect and utilise student’s preference information in retrieving information. OERs are uniquely placed to meet all these requirements with minimal efforts and so a fourth requirement is that a PL system should be implemented as an OER. Finally, we described the architectural features that a platform must have to be able to implement effective PL.

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ENGINEERING EDUCATION PEDAGOGY – NEED FOR A PARADIGM SHIFT:
A CASE STUDY OF PROJECT BASED LEARNING IN CONCRETE TECHNOLOGY

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ABSTRACT
This paper examines the prevalent pedagogical method of training engineers and technologists in tertiary institutions in Nigeria. It notes the passive nature of the method and its incapability of producing graduates of adequate skills that wholly meet the needs of the industry. The paper advocates a paradigm shift from passive to active teaching methods which put students at the centre of learning. A case study is presented of the application of Problem-Based Learning (PBL) to mix design in concrete technology at the University of Lagos. The project is targeted at determining the materials needed for the production of one cubic meter of concrete. The adopted method was based on Road Note 4. In the method, the aggregate/cement ratio is tabulated against the water/cement ratio and degrees of workability for various maximum aggregate sizes and particle shapes. Each group of students worked on a given water/cement ratio while each student has his/her aggregate/cement ratio different from the others. At the end of the exercise, each group identified the variation in the quantity of materials required to produce concrete of the same strength under varying aggregate/cement ratios. The exercise assisted the students to better understand the concept of variation in the components of concrete with changes in some parameters including aggregate/cement ratio, water/cement ratio etc. The paper shows some challenges militating, against the use of innovative pedagogy by the academic staff in the universities. It recommends the need for the training of engineering and technology educators in the use of innovative teaching methods so that the training efforts will be student centred.

RESUME
Cet article examine la méthode pédagogique répandue de formation des ingénieurs et des techniciens dans les établissements d'enseignement supérieur au Nigeria. Il relève la nature passive de la méthode et son incapacité à produire des diplômés dotés de compétences adéquates qui répondent entièrement aux besoins de l’industrie. L’article préconise un changement de paradigme des méthodes pédagogiques, depassives à actives, qui mettraient les étudiants au centre de l’apprentissage. Une étude de cas sur l’application du Problem-Based Learning (PBL) est à cet effet présentée, associant la conception à une technologie concrète du béton à l’Université de Lagos. Le projet vise à
déterminer les matériaux nécessaires à la production d'un mètre cube de béton. La méthode adoptée est basée sur la Road Note 4 : le rapport agrégat/ciment est tabulée en fonction du rapport eau/ciment et des degrés de travail abilité pour différentes tailles et formes globales maximales de particules. Chaque groupe d'élèves a travaillé sur un rapport eau/ciment donné tandis que chaque élève disposait d’un rapport agrégats/ciment différent. A la fin de l'exercice, chaque groupe a déterminé la variation de la quantité de matériaux requis pour la fabrication du béton de la même résistance sous divers rapports agrégats/ciment. L'exercice a aidé les élèves à mieux comprendre le concept de variation dans les composants du béton avec des changements dans certains paramètres, incluant les rapport agrégats/ciment, eau/ciment, etc. L’article présente quelques défis qui militent contre l'utilisation d'une pédagogie innovante par le staff académique dans les universités. Il recommande la nécessité de la formation des ingénieurs et des éducateurs technologues dans l'utilisation des méthodes d'enseignement novatrices afin que les efforts de formation soient centrées sur l'étudiant.

1.0 INTRODUCTION
Engineering education plays an important role in the pursuit of a more sustainable world by providing an enabling environment to produce quality engineers who are change agents. It is the process of training engineers for the purpose of initiating, facilitating and implementing the technological development in the society; it focuses on the methodology of teaching and learning process, assesses the effectiveness of teaching techniques, it evaluates the appropriateness of curricula of engineering programmes, infrastructure, accreditation system as well as industry inputs to the training of engineers. Engineering education concerns two principal facets of education namely; teachers and the students, that is, the instructors and the future practioneers of engineering, it bothers on the development of programmes that will enhance the competence of the teachers and improve their skills while the students are better equipped with knowledge. It thus concerns the study and practice of how best to teach. Because in faculty of engineering, teaching is not an integral part of the courses to be studied and no formal training in teaching after engagement as teachers, most lecturers adopted the teaching styles of their lecturers and therefore at best they can only be as good as their teachers.

The objectives of the engineering training are in consonance with the realisation of national needs and aspirations vis-à-vis industrial development and technological emancipation. The graduates are expected to be resourceful, creative, knowledgeable and able to perform the following functions (NUC, 2007):
(i) Design engineering projects and supervise their implementation.
(ii) Design and implement components, machine, equipments and systems.
Design and develop new products and production techniques in industries

Install and maintain complex engineering systems so that they can perform optimally in our environment.

Adapt and adopt exogenous technology in order to solve local engineering problems

Be able to exercise original thought, have good professional judgement and be able to take responsibility for the direction of important tasks.

Be able to manage people, funds, materials and equipment.

Improve on indigenous technology to enhance local problems solving capability.

The philosophy and objectives of engineering programmes in the universities indicate high expectation from engineering graduates in terms of high academic standard and adequate practical background for self employment as well as being of immediate value to the industry and the community in general. However, the reports from the industry show that these objectives have not been adequately met and therefore in order to achieve the set goals for engineering disciplines, there is a need to reposition and restructure engineering education in Nigeria for necessary industrialisation and development to take place. Most times, the observed inadequacies in the quality of graduates have been attributed to the inadequacies in curricula for engineering disciplines. But apart from the curricula, there are other factors militating against production of quality graduates namely:

(i) The adoption of traditional method of teaching
(ii) Poor staffing
(iii) Weak university/industry partnership
(iv) Poor funding

The traditional method of teaching consists of teachers reading out while students sit submissively taking notes. Atimes, depending on the nature of a lecture, students may abandon the on-going lecture and be reading notes for other lectures, having discussion with their colleagues, pinging, chatting on WhatsApp, working on assignments for another course, some sleeping while others are anxiously waiting for the class to come to an end. The method is passive and does not focus on practical industry application. In the past, this method yielded the expected results because there were few students in each class and placement on industrial attachment in relevant disciplines was effective to complement the training in the universities. It was possible to reach out to each student, but today the enrolment of students has increased tremendously such that the overcrowding of the classrooms has rendered the traditional method ineffective.
Some engineering courses have tutorials as integral part of them. The tutorials provide an interactive platform of transferring knowledge in more specific ways than traditional lectures. They provide a semblance of problem-based learning. In a tutorial class, a lecturer transfers knowledge to students by solving problems, take-home assignments are given to students. The large student population in each class has made tutorials ineffective, ordinarily such large classes should have lectures together but later break up into small groups for the tutorials but the shortage of manpower has negated this arrangement.

For universities to produce engineers with practical and problem solving skills, required by the industry, there is need to change the teachers’ teaching styles to match with the students’ learning styles and therefore a paradigm shift in engineering education pedagogy is required to improve the quality of graduates produced in tertiary institutions in Nigeria.

Most universities in developed countries have adopted several teaching methods that are a shift from passive to active learning and they have been adjudged to yield positive outcome. Universities such as Aalborg University, Denmark, Monash University, Australia, Pennsylvannia State University etc. have adopted project based learning that puts the students at the centre of learning.

2.0 PEDAGOGICAL METHODS
Pedagogy deals with the theory and practice of education; it thus concerns the study and practice of how best to teach (Wikipedia). Teaching refers to the process of imparting knowledge and skills to students. It is an act which encompasses the activities of educating or instructing learners on what they need to know and/or do. It influences the mind, character or physical ability of an individual. Pedagogical methods refer to the principles used for instruction. These methods include class participation, demonstration, recitation, memorisation, or combinations of these methods. These definitions imply that teaching should assist students acquire knowledge or develop appropriate skills to make them function well in the industry after graduation or to be self sustaining and be employers of labour and not job seekers. Learning involves receiving and processing information. The reception component usually involves perceiving new information from one’s external world while the processing aspect of learning is the manner through which the learner uses the new information to increase the richness of his or her existing knowledge. The curriculum should be designed such that the learning activities and their assessment should both be aligned with the learning outcomes which the programme is intended to deliver. Students’ learning styles have been categorised into (i) deep learning and (ii) surface learning. Deep learning refers to the in-depth understanding of information and theories taught (Atherton, 2013). Deep learners take full notes in
class, and afterwards go through them to check on uncertain information. They regularly work through given problem sheets to test if they could apply theories covered during lectures. Surface learners are mainly concerned with the ability to remember important facts and theories given during lectures. They only memorise to pass examinations and do not care about its application. Reyes-Guerra (1989) categorised students into three, namely: Verbalizers, Visualizers and Doers. The verbalizers are those who learn easily if information is in written or spoken form. They benefit from lectures, tutorials and hand-outs. Visualizers learn easily when information is in pictorial or diagrammatic form while the Doers learn more easily when information is presented in form of practical activities. A teacher must identify the peculiarity of his class and select an active teaching method that takes into cognizance the learning style of the majority of students in his class.

There are different teaching methods, among these are:
(i) Team-Based learning
(ii) Problem-Based Learning
(iii) Project-Based Learning
(iv) Outcome-Based Learning
(v) Co-operative Learning
(vi) Flipped Classroom
(vii) Technological Enhanced Learning

2.1 Team-Based Learning
Team-based learning (TBL) is a pedagogical method that uses groups of students in the learning and teaching process in a collaborative manner. It is the use of learning groups to enhance students’ engagement and the quality of students (Michaelsen and Michael, 2012). Team-based learning was developed by Michaelsen et al. (1982) as a potential solution to the problems of large classes. This method allows the involvement of an individual to contribute to the works of others. The contribution of the members of the team is assessed through peer evaluation and the overall team contribution are factored or weighted into the overall grading of each student. In the assessment method, a lot of trust is placed on students believing that they will make a fair assessment of the group members. TBL provides opportunity for weaker students to improve his/her knowledge and it also strengthens the knowledge base of stronger students through their participation in interactive study and learning. It is important that students are sufficiently briefed about the goals, demands and benefits of this method of learning at the start of the course to prepare them for the task ahead and enhance their participation. The working group should be set up without giving consideration to familiarity, ethnicity, friendship etc. In a large class, it important
to combine problem-based or project-based with team-based learning, the procedure is captured later in this paper under the appropriate headings.

2.1.1 Assessment Procedure

After the formation of the groups, a Readiness Assessment Tests (RATs) is given to each group member for an individual solution without consultation. Usually, the teacher is expected to create study guides or reading assignment before RAT. Multiple choice quizzes for the RAT are prepared from the study materials which have been given to each group member. Immediately afterwards, the same test is given to the groups for group interaction solutions (GRATs). There are 3 phases of Team Learning:

i) Phase 1 - consists of independent study to master identified objectives
ii) Phase 2 - RATs
iii) Phase 3 - GRATs (Group Readiness Assessment Tests) and collaborative work

In order to ensure that the individual and group contributions to the activities of a particular assignment are factored into the assessment of each student or team member, the peer evaluation (percentage) method is normally used.

2.1.2 The Peer Evaluation (Percentage) Method

In this method, a percentage multiplication factor is used in computing the final course grade of the students. The grades obtained in the Readiness Assessment Tests for both the individual and group works are used. The group activity grades comprising the RAT, assignments given using a problem based learning method is adjusted by this multiplier and then added to the individual scores which consists of individual RAT scores and Examination grades as well as other individual tests that may have been given.

The points assigned to the individual and group activities should be decided by the group and a consensus taken on the distribution of weighting between the two sets of grades. A safe distribution could be 70% for individual grades and 30% weighting for group work. Each team member is requested to fill the Peer Evaluation Form (Table1), on which an assessment is made of each team member except the assessor, based on:

i) Team member’s preparedness for the lecture to be given.
ii) The level of contribution made by the team members.
iii) Attitudinal disposition, i.e. team members flexibility and accommodation and respect for the ideas of others.
Step 1
Peer Evaluation Result
For example, if there is a team that comprises five members, a sample form is given in Table 1 showing that of Funso:

Table 1: A Sample Form for Team Member – Funso

<table>
<thead>
<tr>
<th>Names of team members</th>
<th>Point awarded out of 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Funso</td>
<td>None</td>
</tr>
<tr>
<td>B Efe</td>
<td>xx</td>
</tr>
<tr>
<td>C Ajibade</td>
<td>xx</td>
</tr>
<tr>
<td>D Ojo</td>
<td>xx</td>
</tr>
<tr>
<td>E Dada</td>
<td>xx</td>
</tr>
</tbody>
</table>

Rules:
Total points to distribute: always = 100
Do not evaluate yourself.

Step 2
The points are then summed up for each team member and express the sum as a percentage as indicated in Table 2.

Table 2: Peer Evaluation Score (PES)

<table>
<thead>
<tr>
<th></th>
<th>Funso</th>
<th>Efe</th>
<th>Ajibade</th>
<th>Ojo</th>
<th>Dada</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funso</td>
<td>-</td>
<td>25</td>
<td>30</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Efe</td>
<td>25</td>
<td>-</td>
<td>25</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Ajibade</td>
<td>30</td>
<td>25</td>
<td>-</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Ojo</td>
<td>25</td>
<td>30</td>
<td>20</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td>Dada</td>
<td>20</td>
<td>30</td>
<td>25</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>110</td>
<td>100</td>
<td>95</td>
<td>95</td>
</tr>
</tbody>
</table>

The total for each team member is expressed as a percentage and becomes the individual peer evaluation score (PES).

Final Course Grading
The final course grading has three components namely:
I) Individual Activities
   a) RAT Score xx
   b) Test score yy
   c) Exams zz
      Total individual score \( \sum (a,b,c) = 'A' \)

II) Group Activities
   a) RAT Score xx
   b) Group Assignment yy
      Total group score \( \sum (a,b) = 'B' \)
Total group score B (This will be the same for all individuals within the group)
III) Adjusted Group Score (AGS) factoring individual peer evaluation score. Multiply AGS = ‘B’ x ‘A’(individual peer eval. %) = ‘C’

This provides a weighting reflecting the individual’s contribution to the group work.

IV) Overall Course Grade = ‘A’ + ‘C’ = ‘D’
Total points earned in course = ‘D’

This is the weighted sum of the individual score and the adjusted group score taking into account the agreed percentage contribution of both activities to the final assessment as discussed earlier.

2.2 Problem-Based Learning
In this method, students are placed in the active role of problem-solvers confronted with situations like the kind of problems they are likely to encounter in the future. This method of teaching develops in learners, thinking strategies, domain knowledge, and flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation (Ifijeh et al; 2013). In PBL, the teacher acts as the facilitator and mentor rather than a source of ‘solutions’ to the problem. The method assists the students to try out what they know, identify what they need to learn, develop skills for achieving performance, improve their communication skills, and equipping the students’ information to defend their positions. It provides opportunity for the students to apply theory to practical problem and equip them with problem solving skills which will make them to be industry-ready after graduation.

2.3 Project–Based Learning
The Project–Based Learning (PjBL) is similar to Problem–based learning. Both methods are based on self-direction, collaboration, and multidisciplinary orientation. Project-based learning has been proved to be one of the effective student-centred strategies in engineering education in many fields (Mills and Treagust, 2003). Project-based learning is based on inductive approach where students’ task is to collaboratively formulate and find answer to question related to course consent. According to meta-analysis (Prince 2004), such active approach to learning was rated to give better learning outcomes than the traditional pedagogical method. Depending on the type of course, Project-based learning requires longer period of time than Problem-based learning; it is more directed to the application of knowledge while Problem–based learning (PBL) is directed to the acquisition of knowledge. This method is also used with team-based learning because of large students’ population in classes.
2.4 Outcome-Based Learning
The concept outcome-based education considers a precise clarification of intended learning outcomes; these outcomes represent students’ desired performance of particular abilities or competencies (Spady, 1994). The pivotal characteristic of the outcome-based pedagogical approach is the emphasis placed on the learning outcomes that are intended to be achieved in the learning environment. The method shifts the emphasis to the question of what abilities the students should possess on the completion of the course.

The outcome-based pedagogical approach of Biggs and Tang (2007) also features the constructive alignment principle, which prescribes the alignment of the individual instructional elements with the intended learning outcomes. Biggs and Tang (2011) indicate that outcome-based design model comprises three parts: the intended learning outcomes, the teaching and learning activities and the assessment tasks.

2.5 Co-operative Learning
Cooperative Learning (CL) is a teaching approach whereby students work in teams on assignment or project under conditions which include the team members being held individually responsible for the complete content of the assignment or project. I have adopted this method in my teaching by identifying weak students, usually after a test has been given and graded. The performance of the students is used to sort them into groups that ensure weak students are put in the group of bright students. Some students, especially, the bright ones, do not admire this method because they see it as weighing them down. The use of this method requires mentoring and counselling of the students.

2.6 Flipped Classroom
In this pedagogical method, many students’ preferences can be addressed using technology. Teachers can make lectures available to students whenever and wherever it is convenient to them, at home, in class etc. Teachers can deliver their lectures and/or instructions by recording and screen casts of work they do on their computers, creating videos of themselves teaching. Instead of talking about phenomena, videos and computer simulation can be used to provide detailed visual representation. Students can access these videos as often as they want. Rather than delivering lectures in the classroom, teacher then use the classroom period to actively engage students in learning process and attend to each student’s need since adequate time is available for discussion (Hamadan et al, 2013). Using video can be better than real life because it enables the instructor to play it over and show it in slow motion if necessary.
2.7 Technological Enhanced Learning

In technological enhanced learning also called E-Learning, electronic media and information and communication technology are deployed in education to enhance the transfer of knowledge and skills. E-Learning includes multimedia learning, computer-based training (CBT), internet-based training (IBT), web-based training (WBT), online education, virtual learning environment (VLE) etc. Well-designed multimedia application offer potential for reduction of time for formal instruction. E-learning can occur in or out of the classroom. With technological advancement, students can use computer or mobile device to access learning materials anywhere in the world.

The need to use appropriate teaching method cannot be overemphasised. This need is succinctly captured in the study by Singhal et al. (1997).

![Fig. 1: Teaching Methods and Retention Rate (Singhal et al; 1997)](image)

Figure 1 shows that the most effective way to teach engineering courses is to practice by doing and teaching others.

3.0 APPLICATION OF PROJECT BASED LEARNING IN CONCRETE TECHNOLOGY

General course objective

The main objective of this work is to make the students understand the concept that when one components of concrete is changed, that it affects other components of it.
The concrete mix is designed to give a specified strength at the minimum cost. The cost depends on the value of the materials, the labour required for batching, transporting, placing and trowelling and the method of curing. This project sets out to determine the materials combination that will give the expected strength. The materials will then be batched, cast, appropriately cured and tested on the 28th day to check the closeness of the obtained strength value to the projected value.

3.1 Methodology
The mix design method used in this work was based on the approach described in Road Note 4 (1947). In the method, the aggregate/cement ratio is tabulated against the water-cement ratio and degrees of workability for various maximum aggregate sizes and particle shapes. Typical overall grading are given from the estimated water/cement and aggregate ratios, the proportions of cement, water and combined aggregate can readily be computed. Since the grading of aggregate is very important in concrete mix design and can have a considerable effect on the workability and stability of concrete, it was required that the aggregate/cement ratio conforms to one of the four degrees of workability shown in Table 1. Typical mix design computation is presented below:

3.2 Specifications for Mix Design
(i) Characteristic strength $f_{cu} = 25$N/mm$^2$ at 28 day
(ii) Ordinary Portland Cement (BS 12.1971)
(iii) Nominal maximum size of aggregate, 20mm
(iv) Shape of coarse aggregate – irregular
(v) Degree of exposure ‘mild’ (Table 2)
(vi) Fine aggregate river sand (sharp sand)
(vii) Specific gravities
   (a) coarse aggregate - 2.69
   (b) fine aggregate - 2.63
   (c) Portland Cement - 3.05

3.3 Mix Design Calculation
For durability, the minimum cement content = 250g/m$^2$. For a characteristic strength of 25N/m$^2$, the target mean strength for a given grade of concrete is calculated from:

$$f_m = f_c + ks$$

Where:

- $f_m$ = The target mean strength
- $f_c$ = The specified characteristic strength
- $s$ = Standard deviation
- $k$ = Constraint
- $ks$ = Margin strength
A low workability was chosen for this study. From DOE (1975), for a 5% defective:
\[ k = 1.64, \quad S = 8 \text{N/mm}^2 \]

The target mean strength:
\[ f_m = f_c + ks \]
\[ = 25 + 1.6 \times 8 \]
\[ = 25 + 13.12 = 38.12 \text{N/mm}^2 \]

From Table 2:
\[ \frac{W}{c} = 0.55 \]
\[ \frac{A}{c} = 6.2 \]

Where
\[ \frac{W}{c} = \text{Water-cement ratio} \]
\[ \frac{A}{c} = \text{Aggregate-cement ratio} \]

Mix Proportion:
0.55 : 1 : (0.3) (6.2) : (0.7) (6.2) that is,

Water : Cement : Sand : Granite chips
0.55 : 1 : 1.86 : 4.34

\[ \frac{W}{1000} + \frac{C}{1000P_c} + \frac{A_1}{1000P_1} + \frac{A_2}{1000P_2} = 1\text{m}^3 \text{ of concrete} \]

where
\[ W = \text{Weight of Water/}\text{m}^3 \text{ of concrete} \]
\[ C = \text{Weight of Cement/}\text{m}^3 \text{ of concrete} \]
\[ A_1 = \text{Weight of Fine aggregate/}\text{m}^3 \text{ of concrete} \]
\[ A_2 = \text{Weight of Coarse aggregate/}\text{m}^3 \text{ of concrete} \]
\[ P_c = \text{Specific gravity of cement} \]
\[ P_1 = \text{Specific gravity of fine aggregate} \]
\[ P_2 = \text{Specific gravity of coarse aggregate} \]

Final mix proportion is determined from the above relationship:
\[ \frac{0.55C}{1000} + \frac{1.00C}{1000 \times 3.05} + \frac{1.86C}{1000 \times 2.63} + \frac{4.34C}{1000 \times 2.69} = 1\text{m}^3 \]
The calculated cement content must be greater than the minimum required quantity to satisfy the durability requirements. Other components are calculated as follows:

\[
\frac{C}{1000} \times 3.1996 = 1 m^3
\]

\[
C = \frac{1000}{3.1996} \text{ kg/m}^3
\]

\[= 312.54 \text{ kg/m}^3\]

The constituent materials necessary for 1m³ of concrete are

- Water = 171.90 kg
- Sand = 581.32 kg
- Granite = 1312.18 kg

Using a mix proportion of 0.55: 1: 1.86: 4.34

Each group of students worked on a given water/cement ratio while each student has his/her own aggregate/cement ratio different from the others. The only variable factor within the group is the aggregate/cement ratio. At the end of the exercise, each group identified the variation in the quantity of materials required to produce concrete of the same strength under varying aggregate/cement ratios. The exercise provided an opportunity to practically observe how the components of concrete change with changes in water/cement and aggregate/cement ratios.

### 3.4 Outcome

The results of the study provided a better understanding of the effects of variation of the components of concrete on its workability and strength. Students perform better both in theory and mix design calculations by solving the problem individually and coming together as a group to compare notes and discuss. The results of students as monitored for three consecutive years (2012-2015) in that section of the concrete technology show good performance.

After the estimation of the materials required to produce 1m³ of concrete, small scale trial mixes, using the aggregate in known condition of moisture content are carried out. The exercise may lead to making necessary adjustments to the
designed mix to arrive at appropriate combination of component concrete that will meet the strength required as well as durability and economy.

4.0 CHALLENGES TO THE USE OF ACTIVE TEACHING METHODS

The major challenges comforting active teaching methods especially in developing countries are:

(i) Unstable electricity supply to classrooms and lecture halls makes the use of multimedia for the training of engineer almost impossible.
(ii) Inadequate (qualitatively and quantitatively) multimedia facilities.
(iii) Poor internet connectivity.
(iv) Shortage of qualified lecturers.
(v) High student population.
(vi) Differences in learning styles of students can be a stumbling block to the successful adoption of team-based learning.
(vii) The students need to be convinced about the reality of the method.
(viii) Poor attitude of students towards the active teaching methods.

5.0 CONCLUSION

From the foregoing, the following conclusions are made:

(i) Engineering and technology educators need to change from passive to active teaching methods.
(ii) Sensitisation of students about the benefits of the new teaching method will improve the acceptance of the methods by the students.

6.0 RECOMMENDATIONS

(i) The training of academic staff should be a continuous exercise to ensure improvement in teaching and research consistent with the global best practices.
(ii) The use of active based Learning should be encouraged in faculties of Engineering.
(iii) First year courses should include an introduction to the methods of project work and team work required for the rest of the programme.
(iv) Sufficient funds should be provided for the acquisition of multimedia facilities.
Table 1: Aggregate/cement ratios required to give four degrees of workability with different water/cement ratios and gradings 20mm (3/4in) irregular gravel aggregate

<table>
<thead>
<tr>
<th>Aggregate/cement ratio by weight</th>
<th>‘Very low’</th>
<th>‘Low’</th>
<th>‘Medium’</th>
<th>‘High’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading number</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Water/cement</td>
<td>0.35</td>
<td>3.6 3.6 3.5 3.0</td>
<td>3.0 3.0 3.0 2.7</td>
<td></td>
</tr>
<tr>
<td>Ratio by weight</td>
<td>0.40</td>
<td>4.9 4.8 4.6 4.1</td>
<td>3.9 3.9 3.9 3.6</td>
<td>3.3 3.4 3.4 3.2</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>6.0 5.8 5.5 5.0</td>
<td>4.8 4.8 4.7 4.3</td>
<td>4.0 4.1 4.1 3.9</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>7.2 6.6 6.4 5.9</td>
<td>5.5 5.5 5.4 5.0</td>
<td>4.6 4.8 4.8 4.5</td>
</tr>
<tr>
<td></td>
<td>0.55</td>
<td>8.5 7.3 7.3 6.7</td>
<td>6.2 6.2 6.1 5.7</td>
<td>5.4 5.3 5.1</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
<td>9.4 8.7 8.1 7.4</td>
<td>6.9 6.9 6.7 6.3</td>
<td>6.0 5.9 5.6</td>
</tr>
<tr>
<td></td>
<td>0.65</td>
<td>8.0 7.5 7.5 7.3 6.8</td>
<td>$\text{6.4 6.1}$</td>
<td>5.8 5.7</td>
</tr>
<tr>
<td></td>
<td>0.70</td>
<td>8.0 8.0 7.8 7.3</td>
<td>6.8 6.8</td>
<td>6.2 6.1</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>7.9</td>
<td>7.2 7.0</td>
<td>6.6 6.5</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>7.5 7.4</td>
<td>$\text{S 7.0}$</td>
<td></td>
</tr>
</tbody>
</table>

S: Indicates that the mix would segregate

Source: Shacklock (1974)

Table 2: Minimum Cement Content for Concrete Compressive Strength of 20N/mm² or more to Ensure Workability

<table>
<thead>
<tr>
<th>EXPOSURE CONDITION</th>
<th>REINFORCED CONCRETE</th>
<th>PRESTRESSED CONCRETE</th>
<th>PLAIN CONCRETE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nominal Maximum Size of Aggregate (mm)</td>
<td>Nominal Maximum Size of Aggregate (mm)</td>
<td>Nominal Maximum Size of Aggregate (mm)</td>
</tr>
<tr>
<td></td>
<td>40 20 14 10</td>
<td>40 20 14 10</td>
<td>40 20 14 10</td>
</tr>
<tr>
<td>MILD</td>
<td>200 250 270 290</td>
<td>300 300 300 300</td>
<td>200 200 250 270</td>
</tr>
<tr>
<td>MODERATE</td>
<td>260 290 320 340</td>
<td>300 300 320 340</td>
<td>220 250 280 300</td>
</tr>
<tr>
<td>SEVERE</td>
<td>320 360 390 410</td>
<td>320 360 390 410</td>
<td>270 310 330 330</td>
</tr>
<tr>
<td>Subject to Salt Used for de-icing</td>
<td>250 290 320 340</td>
<td>300 300 320 340</td>
<td>340 280 310 330</td>
</tr>
</tbody>
</table>

Source: Shacklock (1974)

REFERENCES


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EVALUATION AND ASSESSMENT IN HIGHER EDUCATION: A CASE OF THE STUDENTS RESISTANCE TO EXAMINATION AND A SOLUTION SCENARIO

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ABSTRACT
The paper presents the case of an examination process in which the students manifested a resistance behavior to evaluation due to various factors linked to the organisation, resources and strategy. Assessment and Evaluation in higher education is one of the most important processes and steps for higher performance of this sector. It is important to understand the processes, by which evaluation goes by in order to optimise it, improve it and engineer better of its systems. The case study presents the scenario of examination process, the resistance and the problem-solving approach adopted by both students and teachers. The result of the study implies that both students and teachers play a major role in the improvement of the assessment processes and derive a model leading to its continuous development.

Key-words: Assessment and Evaluation, Examination process, Students’ resistance to evaluation, Higher education

RESUME
L'article présente le cas d'un processus d'examen dans lequel les étudiants manifestent un comportement de résistance à l'évaluation en raison de divers facteurs liés à l'organisation, aux ressources et à la stratégie. L’évaluation dans l'enseignement supérieur est l'un des plus importants processus et étapes pour une meilleure performance de ce secteur. Il est de ce fait important de comprendre les processus par lesquels elle passe afin de l'optimiser, l’améliorer et concevoir au mieux ses systèmes. L’étude de cas présente le scénario du processus d'examen, la résistance et l’approche de résolution de problèmes adoptée par les étudiants et les enseignants. Les résultats de l’étude implique que les étudiants et les enseignants jouent un rôle majeur dans l'amélioration des processus d'évaluation et en tire un modèle qui conduit à son développement continu.

Mots-clés: Évaluation, processus d'examen, résistance des étudiants à l'évaluation, enseignement supérieur.
1.0 INTRODUCTION
The higher education is composed of various types of systems and approaches leading to the development of students and other types of people for the objective of continuous development of the economic and cultural environment. One of the most important parts of higher education is the examination of a learning process that occurs in the middle or at the end of a course. Nowadays, with the development of higher education practices, examination is replaced by a more focused term that is assessment. According to Heywood (2000), the term assessment is linked to both sides of higher education – Teachers, institutions and students, and it is also sometimes substituting evaluation because this latter is also used to evaluate assessments. The information about the term assessment is taken from the research of Heywood (2006), they state that assessment includes examination, quizzes and exercises and was associated with these terms in the 1970s. Assessment is also to measure effectiveness of institutions and teachers and not only students and learners. Also, there are other assessment methods as self-assessment and co-assessment that are evaluated by students and that have positive features (Van den Bergh, 2006).

In the case of examinations, the teachers use comprehensive types of examinations techniques as multiple-choice questions – mostly referred to written examinations (Heywood, 2000) and other types of examination methods. Also, the assessment type – examination - goes through a specific process in which certainly various types of factors play a major role for its optimal engineering and development. The question is what factors are influencing this examination process and more precisely what challenges and obstacles can slow down this process. Thus, the aim of the paper is to present a case study of an examination process and to analyse it to derive the factors influencing the examination process. The next section presents a literature review on the assessment approaches and methodologies, the research framework explaining in more details the reason behind the study and the fourth and fifth section present the results and discussion with implications for examination process in higher education, the final sections present a derived model from the results and some conclusions.

2.0 LITERATURE REVIEW
The assessment process is composed of various systems and approaches that are continuously developed and improved for higher education high performance. There are various research dealing with the aspects of assessment approaches and thus providing specific strategies and methods for the improvement of assessment in higher education (Palomba and Banta, (1999; Brown and Glasner, (1999). According to Stefani (2004-05), it is important for academicians to understand that assessment methods are an entire part of the learning process and that they
have to develop the necessary skills to move from theoretical studies to practical classroom actions.

Besides, the combination of different assessment forms motivates students to be more responsible and reflective and can be used in different manners in higher education (Dochy et al.; 1999). For instance, the self-assessment can be beneficial for the formative assessments and co-assessment for the summative ones (Dochy et al., 1999); co-assessment is sometimes related to self- and co-assessments (Dochy et al., 1999) and it means that students can evaluate their learning processes but allowing staff to control final assessments (Hall, 1995). Concerning examination types of assessment, according to York (2003), there is a difference among coursework and examination assessment students’ performances. Thus, this leads to the increase of interest toward the understanding of the different types of assessment and the students’ performances.

The summative assessments of teaching are another method of assessment: According to Surgenor (2011), it is considered as a little obstacle to the autonomy of teachers, leading to speculative critics and it is unable to measure teaching processes. Also, these assessments are though providing feedbacks on the courses and teaching and are interesting tools showing the quality of teaching and supporting the involvement of students in the improvement of quality learning (Surgenor, 2011). Also, it is to mention the difference among the summative types of assessments and formative ones in that the firsts are not automatically the sum of the seconds because they differ in criteria judgments and information focus.

Formative assessment is criterion-referenced and thus take into consideration the stage of skills and specific learning content reached by the students, whereas the summative assessments means the sum of evidences and not a set of judgments, and the description of the overall learning achieved at a certain time (Harlen and James, 1997). Also following this research, Nicol and Macfarlane-Dick (2006) states that formative assessments and self-regulated learning are two concepts that should be linked to empower the capacities of the students to regulate by themselves, their behaviour, thinking and motivation during learning process.

3.0 RESEARCH FRAMEWORK
The examination type of assessment is one of the most important systems in higher education. It is composed of various types of examinations as multiples choice questions, short essays and others. According to Struyven et al. (2005), the students learning process is based on the assessment methods used and vice-versa. Also, the students prefer MCQ exams to essays but they do not favor them
when there are better evaluation methods. According to Linn et al. (1991), the existing assessment methods is calling for the generation of new types based on more complex criteria for a better evaluation of the performance. Also, it is to consider that students play a major role in the improvement of the assessment methods (Falchikov, 2013); peer-assessment made by students is similar to teacher marks when judgment is based on understood criteria, and it is similar to faculty assessment when academic products and processes are rated (Falchikov and Goldfinch, 2000).

The research of Mc Dowell et al. (2010) through the analysis of a large set of course-experience questionnaires filled by the students and that are assessments for learning, state that student experience is based on staff support, module design and active engagement. Also, the research of Van Der Vleuten (1996) uses a framework to understand assessment utilities and to enable compromise and trade-off in examination practices. The research of Stiggins [2002] states that, in order to improve students’ performance, classroom assessment need to be seriously taken into consideration; to invest in assessment of learning, to start programs to make available the necessary resources for teachers, to provide professional development programs to teachers concerning assessment, to change licensing standards about certifications to show there is competences in assessment.

From the literature review and the research framework, we can see that various research focalise on the performance aspects of the students according to the learning processes and assessment types stating that performance do depend on various factors. This means that there are various factors in higher education impacting on this effectiveness. For instance, it is to mention that there can be quality issues in higher education as lack of resources whether IT-based or organisational-based affecting course classes, their course works and examinations processes and obviously affecting the learning process of the students. Also, more precisely, the focus of the research is on the behavior of the students during examination process that can slow down the on-going process of examination and on the behavior of the teachers and administration to overcome this. The term resistance is used to define the various behaviors of the students leading to the decrease in efficiency of an examination process and the different solutions proposed by them and the teachers.

Thus, the research frames the following research questions:

- What is resistance to examination?
- What the reasons for resistance to examination are?
- What is the possible solution to this resistance?
3.0 RESEARCH METHOD
The research uses a case study to answer the research questions on resistance to evaluation. The case study research method is an empirical research investigating on a phenomenon within its real-life context (Yin, 2009). Also, since this case study is in the context of education, the research also uses the evidence-based practice that is a methodology leading to decision-making based on evidences and on the subject of the study characteristics, situations and preferences (Melnyk and Fineout-Overholt, 2005). Also, in education studies, the case study approach is used to facilitate the understanding of learning and assessment (Stefani, 2004-05).

The data collection method was based on synchronous and asynchronous processes in which data about the situation were recorded according to each occurring event; the major units of analysis were the students, the teachers and the administration of the higher education institution. The data collection method is based on interactions based on discussions occurring at a face-to-face and IT-based manner among the researcher and the teacher, the students and the administration, the observations of the researcher during these interactions; the data were collected through hand-written notes and use of the emails.

4.0 RESULTS
4.1 The context of the case study
The examination process is undertaken to assess the capacities of the students of a specific two course modules organised during the second semester of the academic year 2012-2013. The students are in their 1st year of an undergraduate program of civil engineering in a higher education institution majorly focused on engineering aspects of the environment and they are 75 students. The courses in this module were in a period of 10 to 12 weeks and related to the learning of innovation and design methods for to build the capacities of the students in innovation and creativity for their final engineering project, their on-going higher education and their future jobs. The module assessment system is including three types of important grading elements that are a mid-term exam, group and individuals exercises and course works and practical experiments, and final projects.

With the administration and the students, the mid-term exam was agreed on to be on the middle of the 10-12 weeks and at this time the necessary information about the date, time, and room for the examination was provided to the students and also the type of examination. This latter is a multiple-choice questions exam of 1h50min with the answers corresponding to the choice of some specific words or sentences and the development of two or three short essays, and there are two
sets of papers because the examination is on the two courses in the module; innovation management and design methodologies.

4.2 The problem of the exam: resistance to examination

The exam was scheduled on a Wednesday from 8h to 10h in a large auditorium to fit the number of the courses students and thus provide them with enough space for concentration and orientation. After the organisation of the auditorium classroom tables and desks, the teacher started distributing the exam copies to the students and then provided some final explanations about the exam as the time allowed for exam fill-in and answered the general students’ questions about the exam; For instance, one student mentioned that one multiple-choice question was repeated and thus she informed all the students about this or another student asked more explanation about a question and the teacher clarified it.

As another first reaction to the exam copies, the students were surprised by the type of exam even though they knew in general before that there would be a multiple choice questions; at the beginning of the module, the program was stating that there would be three types of assessment: coursework’s, exam and final project. The teacher also recalled during various class meetings the assessment system because some students were starting to ask for more details about it. After a while during the examination process, some started shouting about their incapacity to answer the questions for the following reasons:

- The exam is too long;
- The exam is too difficult; they do not understand the questions.
- There is too many noise, we cannot write, because some were shouting and the others were writing.

The teacher remembered that during the courses’ classes, there were delays in doing the coursework and practical experiments which can have influenced the level of learning processes of the students and led to lack of knowledge assimilation. The main reason for this was that the students were either absent from class or that they did not have computers –various course works was on the computer.

At a certain point, they decided to stop fill-in the exam and approximatively half of them wanted to go out from the classroom. After that, the teacher tried to stop them and to convince them that they should finish the exam by stating that:

- The questions are related only to the classroom course and that there is nothing else external to this.
- Multiple choice questions are a method of examination that facilitates to students and teachers the evaluation process.
- The students have the time and are allowed to have more than 1h50 min to fill-in the questionnaire.
Some of the students were convinced to continue fill-in the multiple choice exam, but some continued shouting because they lost the exam paper in the crowding situation. Fortunately, the teacher had additional copies and started providing and distributing them to these students. At the same time, hearing the shouting, some other teachers came to support the evaluation process and tried to convince the students that they shall finish the exam. Also, this process of additional teachers for the surveillance led to the quietness of most of the students that continued then fill-in the questionnaire. After a while, the supporting teachers left the auditorium and the shouting started again. The teacher proceeded with the same process of convincing the students for to finish the exam.

4.3 Half-way to the solution: completing the exam

Finally, after 1h50 min, most of the students had finished the exam and another problem occurred related to the provision of the teacher with the copy of the exam. The students were frightened again about the results of examination because of their possible lack of capacities to answer or because of the disturbing conditions of the examination process. The most important statement of the students was: ‘We would like the teacher to consider this evaluation as an exercise or practical experiment only and that we do not need an exam evaluation and that we will at the end of the semester provide the teacher with a final project for evaluation of the capacities of the students’. The teacher responded that: ‘it is already agreed on that there would be a final project and that the share of the courses final note already includes course works that are made during class courses’. The teacher could not convince them to return the exam copies after 30 minutes of negotiation and both the teacher and students started leaving the classroom.

At this point, from separate sides, at the administration of the department, the teacher was requiring a sanction or return of the exam copies for evaluation and assessment and the students were requiring that the exam is to be cancelled and that there would be only the final project. The administration contacted the responsible of the class asking for a report about the situation and also to return the copies. The responsible promised to convince the students to return all copied by next week. The teacher received this good news, and tried to convince the administration that this was not very ethical and that the students might discuss among them the exam and that the evaluation grades would not be fair. Nevertheless, the teacher waited for the copies hoping that it will be returned prior to the coming week. In the meantime, the teacher continued the class courses with the students and tried various times to have other explanations and reasons for this behavior. The students were still giving the same explanations.
4.4 The final solution to the problem

The classes last after the exam about 4-5 weeks and the discussion about the final project was starting. And during one of the class course, the teacher mentioned again the exam issue stating the following:

- The teacher has confidence in the capacities of the students in answering the questions.
- The multiple choice questions is not difficult as the students have started understanding more deeply the subject matter of the entire module;
- The grading systems require to have an evaluation assessment of the exam

After two weeks from the exam, one unique student decided finally to return the exam to the teacher. The other students also decided to return the exam progressively according to the class hour’s schedule. The responsible of the class decided to collect all the copies of the students and provide them to the teacher at once.

5.0 DISCUSSION

The results show that through a long-term negotiation among the administration, teacher, and students, these latter finally decided to return the exam copies to the teacher. This case study of resistance to examination shows that various factors can be considered to overcome this scenario of resistance. These latter can also be defined as the obstacles occurring during an examination process and their solutions. In this case, it is interesting to discuss firstly, the students’ perception of the multiple choice question. The students considered the type of questions as difficult; they considered they have lack of capacities in answering the questions.

Second, they did not consider the conditions in which the exam is taking place as satisfying; the noise of other students and the auditorium. It is to mention that the lack of quality in the examination method as for instance lack of electronic evaluation tools can also be one of the important conditions for a good quality examination process.

Third, they considered that there was not enough time for the length of the exam. Fourth, in order to resolve their own disappointing situation, they agreed on the correspondence of the exam to a simple coursework.

From another side, the teacher’s perception of the exam situation was also interesting. First, the teacher insisted on the exam validation through negotiation because of the grading systems; the teacher considers this system as fair and contributing to the development of the capacities of the students.

Second, the teacher considered various factors for to negotiate with the students to increase their perception of the benefits of the exam. They mentioned the
easiness of the exam because it is only courses content, the increasing capacities of the students during course period to understand the content of the exam, and the importance of self-confidence of the students.

Third, the teacher decision to provide more time for the exam tasks was also a strategic element, considered at that moment as more appropriate, to further slow-down learning process evaluation of the students and decrease stress related behaviors of the students and allow them to provide less efforts in examination.

5.1 Implication to higher education examination

The results and discussion of the study highlights an important issue during examination process and provide a derived solution so to resolve the problem. The paper thus derives from the case study several implications to higher education examination as follows (Taifi, 2013):

First, it is important to take into consideration the resources put in place for the organization of the examinations periods; this can affect the concentration of the students during exams and the evaluation of their learning process. It is to mention that computer-based simulations can be a strategic tool for the improvement of examination process and assessment methods.

Second, it is not to deny or neglect the opinion of the students’ on the examination process in order to resolve the problem occurring at that stage. In fact, the students’ assessment of the learning and examination process can lead to the identification of new ideas and to the improvement of the teachers’ and students’ self-assessments methods. The engineering of high technological-based systems and techniques for both assessment and examination can play a strategic role in the development of higher education.

Third, it is to consider the continuous devotion of the teachers and administration for the problem-solving in the examination process; the assessment and evaluation process is a part of the education engineering and development and thus have a share in the education reforms. The engineering of advanced methodologies of assessment and examination is a strategic plan to adopt for the development of higher education in which the focus is on people, organisations and technologies.

Fourth, it is to take into consideration the education program and modules under which the examination process is taking place. The learning process and learning approaches used by the students in the different contexts can impact the behaviour of students in examination and assessment process.
ACKNOWLEDGEMENTS

We would like to thank the students’ of the examination and module’s courses of this academic year 2012-2013 and the department, the administration and teachers that were the major actors of this scenario of resistance to examination process and its resolution.

REFERENCES


MODELLING RATING SCALES OF QUALITATIVE AND QUANTITATIVE FACTORS: THE CASE FOR CHOOSING BEST UNDERGRADUATE SENIOR PROJECT TITLE

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ABSTRACT
Rating scores of different factors for different alternatives is one of the most important steps for engineering undergraduate students to select best alternative project title or alternative design. However, majority of the students fail to achieve this step due to lack of knowledge of rating scores of different factors on a common scale before ranking alternative weights in order to achieve the best option. The situation becomes more difficult if the factors are a combination of qualitative and quantitative magnitudes. In some cases, within the quantitative factors there could be factors which are agreeing, conflicting or with neutral measures. In this paper method of rating scores on a common scale of qualitative and quantitative factors for given alternatives is provided. Furthermore, the paper provides a case study to enable students understand the importance of rating scores on a common scale of different factors for different alternatives before selecting the best option.

Keywords: Project Based Learning, Rating Scores, Selection of best alternative

RESUME
Noter les scores de différents facteurs parmi différentes alternatives est l'une des étapes les plus importantes pour les étudiants en ingénierie de premier cycle en vue de sélectionner la meilleure alternative de titre de projet ou de conception. Toute fois, la majorité des élèves ne parviennent pas à atteindre cette étape en raison d’un déficit de connaissance sur la notation des scores de différents facteurs sur une échelle commune avant le classement des poids alternatifs afin d'obtenir la meilleure option. La situation devient plus difficile si les facteurs sont une combinaison de grandeurs qualitatives et quantitatives. Dans certains cas, parmi les facteurs quantitatifs, il pourrait y avoir des facteurs qui sont soit en accord, soit en contradiction, soit définis avec des mesures neutres. Dans la méthode étudiée dans cet article, la notation des scores sur une échelle commune de facteurs qualitatifs et quantitatifs, pour des alternatives données, est proposée. En outre, l'article fournit une étude de cas pour permettre aux étudiants de comprendre l'importance de la notation des scores sur une échelle commune de facteurs différents pour différentes alternatives avant de choisir la meilleure option.
1.0 INTRODUCTION

One of the processes in the execution of senior project for undergraduate engineering student is choosing the best option among given alternatives. The process is done by evaluating factors and getting the weight of each alternative, of which eventually are ranked to determine the best option. However, students confront difficult decisions when they come across mixed factors of qualitative and quantitative data. In many instances, students normally list advantages and disadvantages of factors in one alternative which might not be the same in the other alternatives. Even if all factors considered in one alternative are the same in other alternatives the question is to what degree of the advantages or disadvantages which one alternative can be compared to others. Sometimes factors selected are a mixed of qualitative and quantitative data which their scores cannot be compared. In particular, comparison become more complicated if quantitative measuring values are of different measuring units or some of the factors’ scores of a given alternative are either agreeing or conflicting.

Therefore, the objective of this paper is to present a method of rating scores of qualitative and quantitative factors on a common scale before calculation of weights of each alternative prior ranking the alternatives in order of preference so that the best option could be determined. Specifically, the paper aims at undergraduate engineering students rating scores of a combination of qualitative and quantitative factors in the process for choosing best senior project title or best engineering design.

Normal method of ranking different alternatives in order of preference is done by adopting the following procedure (Kothari 1990; Norton, 1999):

a) Identify alternatives,
b) Determine factors,
c) Calculate weighting factors,
d) Ascertain the ranking of factors in the process of calculating the weighting factors,
e) Award scores for all factors on each alternative,
f) Rate the scores of all factors for each alternative on a common scale, and
g) Rank the alternatives.

NOTE: This paper is only concerned with item (f): rating the scores of all factors for each alternative on a common scale.
2.0 Rating on a Common Scale
A given alternative can have many factors with qualitative and quantitative data. Because factors of qualitative might not have attributes of the same nature, or factors of quantitative might not have measurements of same units or sometimes some scores of alternative might be agreeing while others conflicting, it is therefore, desirable to rate the score of all factors on one common scale before calculation of weight of each alternative prior to ranking them in order of priority.

To understand this technique let us consider data picked from the senior project report of a bachelor of engineering student. One of the steps in that report was to select the best option of the design of a Baking Cake Oven. The factors which the student used to select the best design are safety, durability, productivity, price and cooking temperature. It can be noted that the factors are mixed of qualitative and quantitative data. The assessment of qualitative data depends on human opinion. Within the quantitative data there are data which are agreeing, conflicting or of neutral values as can be noted (Table 1). The required results of agreeing factors are values of higher scores (refer column of durability and productivity on Table 1) while the required results for conflicting factor are values of lower scores (refer column of price). However, the best result of a neutral value factor is neither of higher nor of lower but of a neutral score (refer column of cooking temperature: the moderate temperature is 150°C).

Table 1: Scores of Different Designs of Baking Cake Oven

<table>
<thead>
<tr>
<th>Alternative Baking Cake Oven</th>
<th>Factors</th>
<th>Safety</th>
<th>Durability (years)</th>
<th>Productivity (kg/hr)</th>
<th>Price ($)</th>
<th>Cooking Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Poor</td>
<td>12</td>
<td>75</td>
<td>100</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Good</td>
<td>7</td>
<td>65</td>
<td>80</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>V/Poor</td>
<td>4</td>
<td>80</td>
<td>160</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>V/Good</td>
<td>3</td>
<td>35</td>
<td>120</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Good</td>
<td>6</td>
<td>20</td>
<td>80</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>

The student faced dilemma in choosing the best baking cake oven because:

a) Baking Cake Oven alternative A is best in durability,
b) Baking Cake Oven alternative B is best in price,
c) Baking Cake Oven alternative C is best in productivity and cooking temperature,
d) Baking Cake Oven alternative D is best in safety, and
e) Baking Cake Oven alternative E is also best in price.

Eventually the student chose Alternative C because it is best in two factors.
This solution does not prove that alternative C is best because each factor has got its own weighting factor. Therefore what was supposed to be done is as follows: Determine the weighting factor, convert the measured value to obtain the rated score, multiply the rated score by weighting factor to obtain the weight of each alternative for a given factor, adding all weights of each alternative, and eventually rank the weights of all alternatives to get the best option. As mentioned earlier that this paper is concerned with converting the measured value into rated scores. Therefore the data picked from the undergraduate engineering student report are presented in the subsequent sections to show what the student could have done to determine the best design of baking cake oven.

2.1 Qualitative Scores
Qualitative scores are not in numerical form. They depend on human opinions such as level of satisfaction, amount of agreement and perceived importance (System wise Consulting 2013). The scores can be rated in the ten-point scale, ranging from best (10) to worst (0) or five-point scale, ranging from best (5) to worst (0) or any convenient point of scale (Friedman and Amoo 1999). The scores could be based on the performance (very good, good, fair, poor, and very poor), on the recommendation (very likely, likely, neither likely, nor unlikely, unlikely, and very unlikely) or on requirements (always, usually, occasionally, rarely, never) (Rohrmann, 2007).

2.2 Quantitative Scores
Quantitative scores are in numerical form but in different categories. Authors have formulated rating equations of
a) Quantitative factor of different units,
b) Agreeing Factors (the required results is always of high value, such as durability – best results is the one which stays many years),
c) Conflicting Factors (the required results is always of low value, such as price – best results is the one of lowest price),
d) Specific Requirement Factors (the required results is the one which is closer to neutral value – such as blood pressure – the healthiest person is one with blood pressure closer to normal value, 120/80 mmHg).

2.2.1 Rating the Quantitative Scores of Different Units
Rating the quantitative factor of different units, such as weight (measured in kgs), distance (measured in m) or time (measured in seconds) is done as follows: First, neglect the units and establish a convenient scale, say from 0 to 10, then establish a rating formula by multiplying the measured value \( R \) by the ratio of highest measured value \( R_{\text{max}} \) of the respective factor to a maximum number on the established scaler as \( R(R_{\text{max}}/R_{\text{max}}) \), refer column of Durability and Productivity in Table 2. On the column of Durability the highest measured value
(neglecting the measuring unit) is 12, the maximum number of the established scale is 10, thus the converting equation is \( R(10/12) \). Similarly, on the column of Productivity the highest measured value (neglecting the measuring unit) is 80 and the maximum number on the established scale is 10, thus the converting equation is \( R(10/80) \). Now the entire columns of alternatives measured values can be converted into rated score as listed on the respect columns.

Table 2: Rating of qualitative and quantitative factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agreeing</td>
<td>Conflicting</td>
</tr>
<tr>
<td>Better option depends on Human opinion</td>
<td>Better option is the one with higher recorded value</td>
<td>Better option is the one with low recorded value</td>
</tr>
<tr>
<td>Safety</td>
<td>Durability</td>
<td>Productivity</td>
</tr>
<tr>
<td>Key: V/Poor = 0 - 2.5</td>
<td>Poor = 2.6-5.0</td>
<td>Good = 5.1 - 7.5</td>
</tr>
<tr>
<td>Rated Score</td>
<td>Rated Score</td>
<td>Rated Score</td>
</tr>
<tr>
<td>( R(10/12) )</td>
<td>( R(10/80) )</td>
<td>( 10 - R(10/160) )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Recorded Score, R</th>
<th>Rated Score, r</th>
<th>Recorded Score, R (years)</th>
<th>Rated Score, r</th>
<th>Recorded Score, R (kg/hr)</th>
<th>Rated Score, r</th>
<th>Recorded Score, R ($)</th>
<th>Rated Score, r</th>
<th>Recorded Score, R (°C)</th>
<th>Deviation (Capacity – Rated value)</th>
<th>Rated Score, r</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Poor</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
<td>75</td>
<td>9.4</td>
<td>10</td>
<td>3.75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>B</td>
<td>Good</td>
<td>6</td>
<td>7</td>
<td>5.8</td>
<td>65</td>
<td>8.1</td>
<td>80</td>
<td>5.00</td>
<td>100</td>
<td>50</td>
<td>8.0</td>
</tr>
<tr>
<td>C</td>
<td>V/Poor</td>
<td>1</td>
<td>4</td>
<td>3.3</td>
<td>80</td>
<td>10.0</td>
<td>16</td>
<td>0.00</td>
<td>150</td>
<td>0</td>
<td>10.0</td>
</tr>
<tr>
<td>D</td>
<td>V/Good</td>
<td>8</td>
<td>12</td>
<td>10.0</td>
<td>35</td>
<td>4.4</td>
<td>80</td>
<td>2.50</td>
<td>200</td>
<td>50</td>
<td>8.0</td>
</tr>
<tr>
<td>E</td>
<td>Good</td>
<td>6</td>
<td>6</td>
<td>5.0</td>
<td>20</td>
<td>2.5</td>
<td>12</td>
<td>5.00</td>
<td>250</td>
<td>100</td>
<td>6.0</td>
</tr>
</tbody>
</table>
2.2.2 Rating the Quantitative Scores of Agreeing Factors
If the quantitative factor is agreeing the rated score start from the highest number on the established scale for highest measured value, columns of durability or productivity in Table 2.

The rated score can be calculated as follows:
- Determine the maximum measured value: \( R_{\text{max}} \),
- Determine the maximum rated value: \( r_{\text{max}} \),
- Calculate the rated score by using the following equation: \( R(\frac{r_{\text{max}}}{R_{\text{max}}}) \)

2.2.3 Rating the Quantitative Scores of Conflicting Factors
If the quantitative factor is conflicting the rated score start from the highest value on the established scale for lowest measured value, refer to column of price in Table 2.

The rated score can be calculated as follows:
- Determine the maximum measured value: \( R_{\text{max}} \),
- Determine the maximum rated value: \( r_{\text{max}} \),
- Calculate the rated score by using the following equation: \( r_{\text{max}} - R(\frac{r_{\text{max}}}{R_{\text{max}}}) \)

2.2.4 Rating the Quantitative Scores of Specific Requirement Factors (Moderate)
If the quantitative factor requires a specific requirement (moderate value) this means that the best score is neither of the highest value, like in the case of agreeing nor of lowest value, like in the case of conflicting but a neutral or moderate value. For example, the normal blood pressure is 120/80mmHg. In this case we cannot say that the best healthiest person is the one with the highest measured value (e.g.220/140 mmHg) like the case of agreeing or the one with the lowest value (55/25 mmHg) like the case of conflicting. The healthier person in such situation is the one with neutral value (120/80 mmHg) or closer to this value. In such a case, the score is rated highest at the neutral point, then decreasing as the measured values deviates positively or negatively from the neutral point, refer column of cooking temperature, Table 2. The rated score can be calculated as follows:
- Determine the normal value: \( R_N \),
- Determine the absolute deviation: \( \text{ABS}(R_N-R) \), R being the measured value,
- Determine the ratio of absolute deviation to maximum rated value: \( \text{ABS}(R_N-R)/R_{\text{max}} \), \( R_{\text{max}} \) being the maximum rated value,
- Calculate the rating score: \( r_{\text{max}} (1-(\text{ABS}(R_N-R)/R_{\text{max}})) \), \( r_{\text{max}} \) being maximum rated score.
3.0 CASE STUDY: SELECTION OF BEST LAPTOP

The authors present this case study to show the difficulty of selecting the best option where a mixed of qualitative and quantitative factors are involved. The research was conducted in higher learning institutions, engineering consultants and multimedia business centres. All these entities are situated in the city of Dar es Salaam.

The survey indicates that common factors the users apply to select the appropriate laptop are price, performance and connectivity features like USB port, build in speakers and android. Students select laptops with budget in mind, but they want highly performance laptops which are portable and ease to use with reasonable display (15 to 17 inches screen). However, users with technical know how specifically want laptops with high hard drive and RAM of at least 4GB and high speed CPU. But, business people prefer laptops with graphics options for engineering drawings and video editing. The factor of price for this group of people really was not a concern. This group indicated that any high performance laptop must be a comparatively expensive. It was noted also that some users choose laptop based on one or few factors with ignorance of other factors. Choices of some users were based on manufacturer’s brands regardless of other factors, while others’ choices were based on usage, place of work or financial budget. None of the interviewees including academic people used the method of ranking different laptops by considering all necessary factors. Therefore, the authors have used this case study to demonstrate how holistically appropriate laptop can be selected. In this case study, a mix of qualitative and quantitative factors against different brands of laptops is shown on Table 3. Before this table is applied the user should consider holistically the following:

a) Usage: games, preparation of reports, graphic works including engineering drawings, editing, etc.

b) Volume of work: Commercial, domestic, academic, official use, etc.

c) Place of work: at home, in the office, at school, at sites, in the factory, in transit, etc.; and

d) Financial budget.

Furthermore before application of this table, the user should know the nature of factors to be used for selecting the best laptop. Some of these factors are as follows:

3.1 Performance

A laptop will perform better if it has bigger Hard-drive, Random Access Memory (RAM) and Central Processing Unit (CPU). Hard drive and RAM are measured in bytes (normally GB). The Hard Drive is the main place of the computer which stores information, the RAM is a temporary working space the computer uses to
get work done, which gets emptied when the computer is turned off. On other hand, a CPU is the brains of the computer where most calculations take place. The performance or speed of a CPU is measured in hertz (Hz) which basically measures the number of operations that can be done per second.

There are two different types of CPUs. There is a 32-bit CPU and there is a 64-bit CPU. The more bits, the more that processor can handle and, since 64-bits is larger than 32-bits, that means that a 64-bit processor is the better choice as it can handle more instructions in one load. Moreover, a 32-bit processor can only handle 4GB of memory, compared to a 64-bit processor which can handle up to 192 GB of memory or RAM (Lai 6).

3.2 Price
The price of the computer depends mainly on the usage. However given equal properties of different computers the customer prefer low price.

3.3 Portability
Users prefer laptops that are lighter in weight, the size of the screen can be anywhere from 7 to 20 inches - the smaller the screen, the more portable the laptop.

3.4 Durability
The laptop should be strong to resist shock, impact, heat or cold and should have battery of longer life. The laptop should also not feel so hot that a person has to move it off his or her lap while working.

3.5 Connectivity
Connectivity such as keyboard, mouse, touch screen, USB ports, built-in speakers, Fire Wire Ports, Ethernet Ports, HDMI Ports, Card readers, Bluetooth, Wi-Fi and Networking (built-in modems) are of most important especially for students.

From the above mentioned factors the method of evaluating the best laptop can be arranged as qualitative or quantitative. Within quantitative there are factors which are agreeing and conflicting or with neutral value as can be seen on Table 2.

This table can be filled in by users after they have identified the usage, volume of work, place of work and financial budget. Once these are determined, method used in Section 2 above can be adapted to rate the scores of all factors for all given alternative on a common scale.
Table 3: Table for Rating Factors for different laptop on a common scale

<table>
<thead>
<tr>
<th>Factor</th>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agreeing</td>
<td>Conflicting</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Durability</td>
<td>Warranty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard Drive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HP</th>
<th>Lenovo</th>
<th>Dell</th>
<th>Panasonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer</td>
<td>Toshiba</td>
<td>Sony</td>
<td>Samsung</td>
</tr>
<tr>
<td>Apple</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.0 CONCLUSION
Research shows that many users are ignorant on what methods should be used to determine appropriate option, in particular when a combination of qualitative and quantitative factors is involved. By applying the model provided in this paper students will be in a position to rate a combination of qualitative and quantitative scores on a common scale prior selection of best project title or alternative design. The case study presented in this paper simply demonstrates how useful the model could simplify the ranking of alternative items in the order of preference.

REFERENCES
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Fig. 1: Interactive funding model and performance feedback

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