Building Nexus for Teaching and Research through the Grand Challenges in Engineering

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ABSTRACT

The National Academy of Engineering (NAE) initiated the fourteen grand challenges of engineering since its inception in 2008. Recently Taylor's University, school of engineering, Malaysia adopted the grand challenge program by aligning the curriculum model towards the NAE thrust areas. In an effort to achieve the school vision and integrate research into teaching, the Computer Intelligence Applied (CIA) wing is established as one of the intiatives in the school. The research projects under the wing are aligned with the grand challenges and embedded into the teaching, bridging the gap between teaching and research in the discipline. This framework ceates a structure where the research output is built into the curriculum, so that the students are on par with real time advancements.

Keywords: *Grand challenges in engineering, research informed teaching, nexus in research and teaching, projects, curriculum*

GRAND CHALLENGES IN ENGINEERING

In the school of engineering, project based pedagogy is combined with a conventional teaching and learning system. In the project based pedagogy learners are given a real world issue and challenged to propose a solution. The projects are in line with the fourteen grand challenges of engineering introduced by the National Academy of Engineering (NAE) as shown in Table 1. These grand challenges are the current engineering problems that need to be addressed for humanity to transition into the next century in a sustainable manner.

They were identified by a panel of experts formed by the NAE as reported by Perry et al. (2008). The grand challenges are classified into four different themes and the grand challenges are imbibed within the themes.

Table 1: Grand Challenges in Engineering

(adopted from NAE)(Perry (2008))

Theme	Scope
Energy & Environment	1. Make solar energy economical 2. Provide energy from fusion 3. Develop methods to carbon sequestration 4. Manage the nitrogen cycle 5. Provide access to clean water
Health	6. Advance health informatics 7. Engineer better medicines
Security	8. Prevent nuclear terror 9. Secure cyberspace 10. Restore urban infrastructure
Learning & Computations	11. Reverse engineer the brain 12. Enhance virtual reality 13. Advance personalized learning 14. Engineer the tools to scientific discovery

FRAMEWORK FOR THE RESEARCH-TEACHING NEXUS

Friedrich and Michalak (1983) claimed that there is no significant correlation between the research and teaching. Hattie and March (1996) presented a meta-analysis of 58 studies demonstrating that the relationship between research and teaching is null. With no clear link between research and teaching, the School of Engineering (SoE) proposed a framework to create a nexus between the two through various research clusters. Research-led teaching is the goal of SoE and initiatives are in place to ensure this objective is met as reported by Al-Atabi et al. (2013). The various research clusters set up within the School to address the grand challenges are expected to contribute towards the achievement of this objective.

Computer Intelligence Applied (CIA) is one of the research clusters established within the school with the objective to foster, promote, and communicate high-quality research and innovation in the fields of medical, environmental, energy, safety engineering and educational applications. The cluster wings under the Computer Intelligence Applied research cluster and the scope addressing the grand challenges are shown in Table 2.

Figure 1 shows one such cluster wing within the CIA research cluster which is aimed at addressing selected NAE grand challenges. Academic, non-technical contributors and international collaborators are invited to support the activities of the CIA research cluster. Based on the selected grand challenges, cluster wings are established. The individual cluster wing then derive the research work through the integration of the various stakeholders including students, advisors, collaborators, funding body etc., The outcomes will be integrated with the modules taught in the programme to enable research-led teaching to take place. Furthermore, the outcomes are expected to form the basis for future experimental and research work.

Table 2: Cluster Wings

Cluster Wing	Grand Challenge	Scope	Research Collaboration*
Sustainable Energy at Taylor's (SE@T)	1,2,3,5,10	Energy, Environment	UNSW, Australia
Intelligence Applied	6,7,9,11,13	Security, Health, Learning	-
Applied Electromagnetics and Mechanics	2,14	Energy, Environment	UiNM, Malaysia
Systems & Control	5,10	Control applications	-

**in progress*

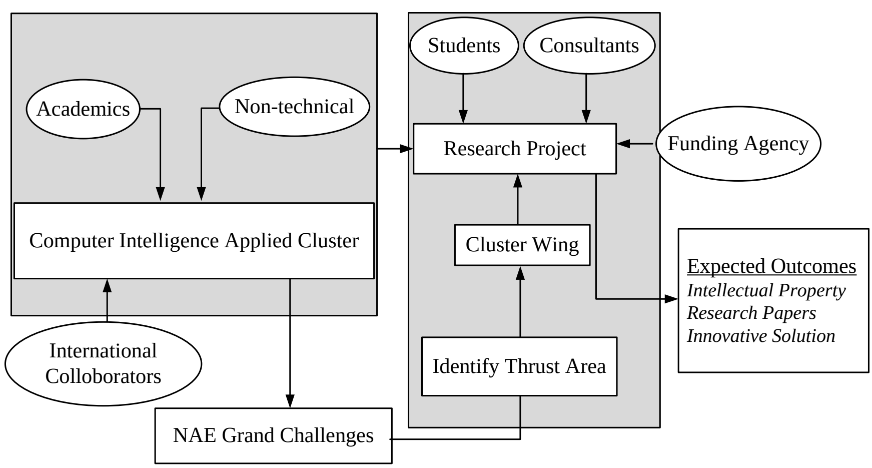


Figure 1: Cluster Wing Model to address the NAE Grand Challenges

Research clusters are based on selected grand challenges and are formed through the initiative and research interests of academic staff. Each research cluster comprises academic staff with research interest and expertise in the same field and the students involved in various projects offered by the cluster. Each cluster is expected to forge links with the industry and with researchers from other academic institutions. These links will continue to be developed and more research clusters are expected to be formed in the future as this initiative matures. Through the research conducted by the clusters, it is anticipated that the gap between research and teaching can be narrowed. Students have opportunity to engage and learn, receive mentoring, be exposed on a first hand basis to the grand challenges, and experience the fruition of their efforts upon the completion of their project.

Knowledge attained through such research will be transmitted by the cluster to the next cohort of students by its incorporation into the curriculum. Consequently synergy is achieved through the School's focus on the grand challenges resulting in the gap between research and teaching being narrowed. The role of the cluster members is to identify resources, identify and attract funding, document the work done and share findings with local and global professionals in the similar research areas in addition to their technical contributions.

Table 3 documents the projects offered by this CIA cluster and relevant information pertaining to them. While not all the current final year projects offered by this cluster directly addresses the respective grand challenges, yet there is indirect connection to them and most importantly these projects present an opportunity to narrow the gap between research and teaching. The projects from the various clusters follow the same objectives in terms of project execution, documentation and information database for future references.

The clusters and the projects are one year old and the cluster wings are in the process of initiating a wide spectrum of collaborative opportunities with universities and research centers locally and internationally. The cluster members' role as co-researchers allow for a better platform for their research expertise. For instance in the project "Maglev based VAWT", one of the members is co-researcher in a government funded project with a postgraduate student from another institution of higher learning. The design of VAWT is intentionally offered in the host university (Taylor's University) at bachelors level as a result of this research activity. Effort is made by the cluster wing members to bring in projects together in order to develop feasible solutions together in a synergistic manner. The project dissemination is accomplished through presenting the work in the seminal meetings in the area of renewable energy. At the moment there is yet to be any official collaborative terms of reference and the CIA is intending to put this in place in the near future.

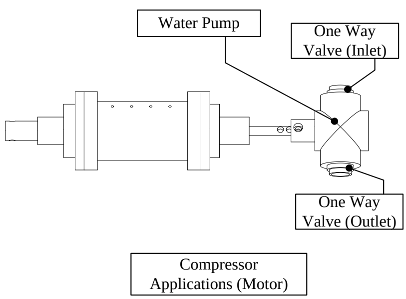
Table 3: Project Descriptions

Research Cluster : Computer Intelligence Applied						
Cluster Wing	**NAE Theme**	**Project Theme**	**Scope**	**Funding**	**Collaboration***	**Students level**
Sustainable Energy @ Taylors	Energy and Environment	Hybrid Photovoltaic for Tourism Industry	Energy Efficiency in hotels and resorts	E-science Grant Malaysia	International University	Bachelors (Host University)**
		Look ahead energy management system for demand control	Energy Efficiency at Taylor's University	-	-	Bachelors (Host University)
Intelligence Applied	Better Infrastructure	Collision Avoidance of ships in a busy port using Bat signal processing (project yet to start)	Improvising infrastructure	Taylor's Research Grant, Malaysia	Port Klang Malaysia	Masters, Bachelors
Applied Electromagnetics and Mechanics	Energy and Environment	Maglev based VAWT	Application of electromagnetic principles in energy conversion	Exploratory Research Grant, MOSTI, Malaysia	Local University	Phd (collaborating University), Bachelors (Host university)
		Wave drive using flux switching induction actuator	Application of electromagnetic principles in energy conversion	School of Engineering, Taylor's University, Malaysia	-	Bachelors in Electrical and Electronics
Systems and Control	Control Applications	Non-linear Level Control for use Chemical Engineering	Application of control in improving plant efficiency	School of Engineering, Taylor's University, Malaysia	-	Bachelors in Chemical Engineering

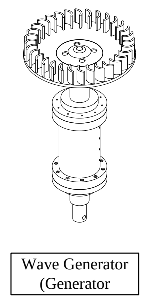
** proposal stage   ** to start in Sep2013*

Figure 2 shows the project outcome and this is proposed to be used for the subjects as in Table 4. Some of the projects are multidisciplinary spanning across three disciplines: Chemical Engineering (CE), Electrical and Electronic Engineering (EE) and Mechanical Engineering (ME).

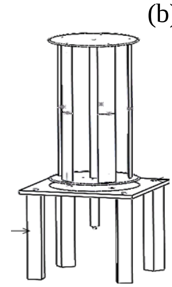
For the case of the Figure 2, the flux switching linear induction actuator is captured as a topic for the following semester's elective course named design of electrical apparatus. The Maglev -VAWT (Figure 2(c)) is proposed to be used for another elective course named renewable and non-conventional energy sources. To perform a mapping of the project to the course learning outcomes, the project duration and execution is monitored and planned based on a scheme of work. The outcome of both projects was presented at international conferences and hence they are contributing towards technological advancement.



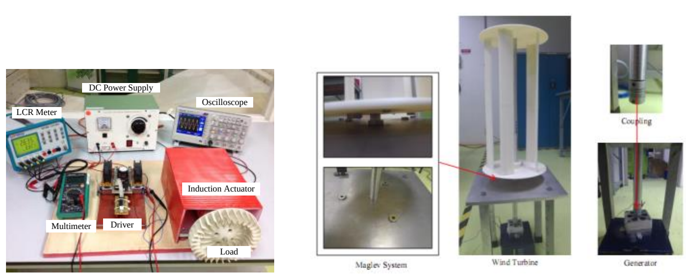
(a) FSLIA as motor



(b) FSLIA as generator



(c) MAGLEV-VAWT



(d) Research work to be embedded in courses in Sep 2013

Figure 2: Research output from the final year projects in May 2013

The biggest challenge to address is to achieve a balance between the course module requirements to that of the cluster objectives. The assessment of the project is based on the course requirements; however the intentional outcome of the project is to produce research solution towards the grand challenges. Table 4 shows the proposed outcome of the research embedded to the taught subjects in the following semester. Embedding the raw research outcome into the course curricula provide an opportunity for the learners to have the experience of current technological advancements. This also provides a key opportunity for them to pursue their research further if it interests them to do so.

Table 4: Nexus of the Research to Teaching

Cluster Wing	Project	Linked to Subject	Taught Level
SE@T	Flux Switching Linear Induction Actuator [Figure 2 (a) and (b)]	Design of Electrical Apparatus	Year IV, Sem 7, EE discipline
	Maglev Assisted Vertical Axis Turbine [Figure 2(c)]	Renewable and alternative energies	Year IV, Sem 7, EE, CE, ME discipline^
Systems &Control	Non-linear Control	Advance Control Systems	Year IV, Sem 7, EE discipline^

^ *in proposal*

Table 5 shows the mapping of the research outcome and its mapping to the grand challenges and also the learning outcomes. This explains the bridge mapping between the project outcomes, their linkage to the grand challenges, the mapping to the learning outcome and the appropriate assessment plan. The imbibing of the outcome into the project module is moderated and endorsed by the cluster representatives before proposing to the school management for final approval. The cluster would look at the impact and sharing of the research outcome with their peers in their area of expertise both locally and globally.

Table 5: Mapping of the research to teaching towards providing the grand challenges solutions

Project Description	**Project Outcomes**	**Grand challenge Solution**	**Learning Outcome of Linked Subject**	**Assessment Plan**	**Expected Outcomes**
Flux Switching Linear Induction Actuator	The developed prototype is tested for applications in wave energy generation (generator) and also in compressor applications (motor)	Replacing the rotary compressor with linear compressor improves efficiency Linear wave energy conversion There is no rotational losses	Evaluate the design of linear machines using numerical methods	Given the research project to the students develop the model using numerical analysis and improve performance by proposing a new design	The outcome of the work would be captured in the subsequent semester for the same course
Maglev Assisted Vertical Axis Turbine	The prototype demonstrated that using the MAGLEV in turbine design improves the generated voltage and reduce vibrations introduced	Energy generated is improved addressing the energy demand issue	Analyze different sources of renewable energies.	The project developed is proposed to be used as a case analysis for the students to provide a further option in improvising the system	The proposed solution by the student is captured for the enhancement of the project in the Final year project work

CONCLUSION

The authors believe that this framework when adopted would support the initiative of the NAE towards a sustainable future while creating a nexus between reserach and teaching. This dynamic model provides an additional dimension wherein the course adopted by the cluster aids the nexus of research into teaching through the grand challenges framework and ultimately produce students who are aligned with the latest developments in research and industry.

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