INFUSING DESIGN THINKING AND SERVICE LEARNING INTO THE DIPLOMA IN CLEAN ENERGY MANAGEMENT (CEM)

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Abstract

Engineering courses traditionally focus on domain discipline knowledge that is often termed “technical knowledge”. However, over the years, the traditional model of engineering studies is increasingly seen as not addressing the needs and demands of today’s fast-changing innovation economy and complex world. Employers are increasingly looking for graduates who are not only excellent in their technical knowledge, but are also able to offer human-centred engineering considerations in addressing complex problems. Critical and creative thinking, clear communication and an awareness of global perspectives are also key attributes expected of engineering diploma graduates. To prepare our students for the future engineering workplace, the Design Thinking and Service Learning philosophy was infused into the curriculum of the Diploma in Clean Energy Management (CEM) course, to cultivate in our students a purposeful learning experience and a passion for lifelong learning.

Design Thinking offers a process for students to infuse user-centred considerations into engineering projects before a product or service is conceived. Service Learning puts a human face on the otherwise cold and hard engineering products and technical solutions. These two pedagogies provide the vertical integration of modules students study from the first to the fourth semesters.

This paper outlines the framework CEM has piloted for the past two years to achieve a more holistic approach to learning design and delivery. In the process “Connecting the Dots” to bring about a better appreciation of how the learning in the various modules are interlinked. The key modules include Clean Energy and A Sustainable Environment (CESE), Electrical and Electronic Practice Skills (EEPS), Clean Energy Mini Project 1 (CEMP1) and Clean Energy Mini Project 2 (CEMP2). These modules are supported by Innovation Toolkits (INNOVA8), Power Electronics Applications and Practice (PEAP), Computer-Aided Design (CAD). The deliberate effort in actively engaging students’ learning within a meaningful service learning context has produced positive outcomes and deeper learning.

Keywords: Design Thinking, Service Learning, Engineering Education, Human-centred Engineering, Project-based Learning

Introduction

The Diploma in Clean Energy Management (CEM) was introduced in 2009 as a result of government and industry consultations regarding the long term skilled manpower needs for the CleanTech sector [1] of the Singapore economy. The diploma is offered as one of the engineering diploma under the Ngee Ann Polytechnic, School of Engineering’s twelve diploma courses in the Electrical Engineering Division (EE). The diploma focuses on clean energy technology and energy management. The diploma’s curriculum was formulated in consultation with relevant industry partners and institutions of higher learning. Course reviews carried out every three years indicated that while the course content have adequately addressed the needs of the industry, students were lacking in the ability to relate contents of earlier semester’s modules with later semester’s modules. Students are learning content in silos and are not able to see the “big picture” or how their learning can impact the community. This results in students who are able to achieve good grades for their individual modules but unable to make use of module content learnt in an earlier semester to better understand a new module.

This “isolated” manner of learning is in contrast to the graduate outcomes that Ngee Ann Polytechnic wants to achieve. In 2015, Ngee Ann Polytechnic announces our Ngee Ann Graduate Outcomes - Passionate Learners, Big-hearted Persons and Global-smart Professionals. In line with this initiatives, NP seek to infuse into our course curriculum more learning opportunities for our students with the community at large. The Design Thinking and Service Learning pedagogies were identified to create such learning...
opportunities for our students. Design Thinking offers a process for students to infuse user-centred considerations into engineering projects before a product or service is conceived. Service Learning puts a human face on the otherwise cold and hard engineering products and technical solutions.

In view of the need to enable students to learn in a holistic manner and to see how their content knowledge has real world application, the CEM team decided to revise their curriculum to infuse Design Thinking and Service Learning into their diploma, with the intent to allow students to appreciate how their content knowledge is applicable to daily life and can support the needs of the community.

The CEM Course Curriculum

The Diploma in Clean Energy Management curriculum covers several core fundamental engineering modules. These are Electrical Technology (ELTECH), Engineering Mechanics (ENGMEC), Engineering Mathematics (EG1) and Computer Programming (COMPRO) in the first semester of studies. In addition, students also study the module Clean Energy and A Sustainable Environment (CESE) and the module Innovation Toolkit (8INNOVA). During the second semester, CEM students take Electrical and Electronic Practical Skills (EEPS) and 9INNOVA modules. In the third semester, CEM students take the Clean Energy Mini-Project 1 (CEMPI) and Power Electronics and Applications (PEAP) modules in addition to their core modules. And for the fourth semester, they take Clean Energy Mini-Project 2 (CEMP2) and Computer Aided Design (CAD) modules.

8INNOVA module focuses on exposing students to various skill sets in the innovation journey & gives students practical insights into design thinking. It aims to foster their creative confidence through an emphasis on observation, ideation techniques and market validation skills.

9INNOVA module enables students to apply skills earlier acquired in 8INNOVA for the School of Engineering (SOE) Creativity and Innovation Week. During the Creativity and Innovation Week, students will showcase and present the final outcome of their design thinking journey.

Design Thinking

The Stanford Arts Institute [2], described Design Thinking as “The process that first defines the problem and then implements the solutions, always with the needs of the user demographic at the core of concept development. This process focuses on need finding, understanding, creating, thinking, and doing. At the core of this process is a bias towards action and creation: by creating and testing something, you can continue to learn and improve upon your initial ideas. The design thinking process consists of these 5 steps:

**Figure 1. Design Thinking Stages**

- **EMPATHIZE:** Students understand the experience of the user i.e. gardeners, receptionists, service crews, and the resort guests in Siloso Beach Resort (SBR) [3] through observations and interactions.
- **DEFINE:** Students process and synthesize their observations and findings from their empathy work in order to form a user point of view that they will address with their proposed solution.
- **IDEATE:** Students explore a wide variety of possible solutions, allowing them to step beyond the obvious and explore a range of ideas.
- **PROTOTYPE:** Students transform their ideas by building a prototype to realize their proposed solution.
- **TEST:** Students test their circuits (prototype) and use observations and feedback to refine their prototypes.

CEM Module Alignment for Design Thinking

Design Thinking was explored in April 2013 as a potential pedagogy to provide the linkage and build understanding between various modules in the curriculum. Design Thinking was chosen as the identified anchor and support modules have learning activities which can be aligned with the various stages of design thinking as outlined by the Stanford Arts Institute.

CEM anchor modules are designed with lectures, assignments, projects and workshop sessions with specific focus on key stages of the design thinking processes. Table 2 shows how various anchor (core) and support modules are mapped into the design thinking processes.
CEM Year 1 students learn key processes (Empathize, Define and Ideate) through the various learning activities in the CESE and EEPS anchor modules supported by INNOVA8 and INNOVA9 modules.

CEM Year 2 students learn key processes (Ideate, Prototype and Test) through the various learning activities in the PEAP, CEMP1 and CEMP2 anchor modules supported by CAD module.

Anchor Modules and Support Modules – Creating the connection between modules

A “Connect-the-Dots” table is shown in Table 3 to better illustrate the relationships between the various anchor modules and support modules over the four semesters. The relationship between the modules will require students to bring knowledge from one module to another. This means that students now have to make their own mental linkages between the different set of content and to learn to see them as a whole rather than just individual modules or topics as they are expected to draw on their previous content knowledge to progress in their project in the modules.

Implementation, Learning Activities and Outcomes.

a) CEM Year 1 Semester 1: EMPATHIZE
CESE, INNOVA8 Modules.

Students are introduced to the Siloso Beach Resort during their first off campus visit. They get to learn...
about the Resort’s various eco-friendly initiatives and how they have actively incorporated corporate social responsibilities into their everyday activities. Sites visited in the Resort include a roof top garden, a no-chlorine used swimming pool, a wormery and a resort in a garden design concept.

b) CEM Year 1 Semester 2: DEFINE and IDEATE EEPS, INNOVA Modules

Students learn to document their observations guided by the acronym POEMS®. They also learn to doodle and share their observations. All observations are documented in a learning journal. Students working in teams make several trips to SBR on their own to interact with staff of SBR and make on-site observations of activities in the Resort. They are allowed to take photographs to capture the situations they have observed. Students brainstorm proposed solutions to address identified ‘pain-points’ as documented in their learning journal. They present and share their proposed solutions with their classmates.

6 An acronym introduced in the INNOVA module for students to be guided during their “Opportunity Spotting through Observations” exercise. POEMS stands for:

- P - Process Explanation
- O - Objects used by the users
- E - Emotion
- M - Multiple Perspectives
- S - Services Rendered

Figure 2. Summary of Year 1 Design Thinking student learning activities.

c) Year 2 Semester 3: IDEATE and PROTOTYPE CEMP1, PEAP Modules

Students learn to translate their proposed solutions into electrical and electronic circuit diagrams using the knowledge they learned from two anchor modules. Students will need to make connections between the 2 modules and propose a workable design that meets the users’ needs. The Clean Energy Mini Projects 1 (CEMP1) Module guides students to build an electrical or electronic application using clean energy at the end of the module. Students are guided in each workshop practice to learn about various practical electronics and electrical circuits, batteries charging and discharging circuits, microcontroller and microcontroller interfacing with sensors, relays, switches, serial and network devices. The Power Electronics and Applications (6PEAP) Module introduces to students the principles of operation and analysis of power conversion circuits such as AC to DC converters, DC to DC converters, DC to AC converters and AC power controllers. Students learn to apply their knowledge in power semiconductor applications to the control and conversion of electric power. Students will learn build and test their circuits as part of their solution.

d) Year 2 Semester: PROTOTYPE and TEST CEMP2, CAD Modules

Students integrate sub circuits into a complete project solution in the Clean Energy Mini Project 2 Module. This module aims to allow students to deepen their knowledge and skills in developing a clean energy application or an energy management system. Students work on mini-projects using skill-sets learnt in Clean Energy Mini Projects 1 to gain hands-on experience and understand how different clean energy technologies are deployed and managed to convert clean energy sources to electrical power. Here, the students assemble and test circuit with a live PV system installed at our Solar Technology Centre in the Polytechnic. Students are also required to use their AutoCAD knowledge to document their circuits and systems by creating digital drawings to be included in their final project reports.

Service Learning: Using their learning for the Community

The adoption of Service Learning in the curriculum is also part of the process to develop our students into “Big Hearted Persons” that cares for the community,
and the willingness to use what they have learnt to serve others.

Service learning was piloted during the April 2014 and April 2015 Induction Week for Year 2 students. Service Learning elements has been added to the course curriculum guided by the following service learning principles. [5] Service Learning activities will involve students in community service activities and applies the experience to personal development. Service-learning occurs when there is "a balance between learning goals and service outcomes". Service Learning differs from internship experience or volunteer work in its "intention to equally benefit the provider and the recipient of the service as well as to ensure equal focus on both the service being provided and the learning that is occurring". Service Learning course objectives are linked to real community needs that are designed in cooperation with community partners and service recipients. In Service Learning, course materials inform student service and service informs academic dialogue and comprehension.

Service Learning engages students in a three-part process: classroom preparation through explanation and analysis of theories and ideas; service activity that emerges from and informs classroom context; and structured reflection tying service experience back to specific learning goals.

On their first trip to the Senior Activity Centre, students engage the seniors in several activities such as serving them afternoon snacks, perform song and dance items to entertain them, help them in the making of small projects and spend time chatting with them to better understand their life and challenges faced. This stage is important as the observations from the visits would allow students to reflect on the areas in which they can make a difference in the daily lives of the Seniors.

During follow up visits, students will start to use their learning from the course to design and develop small projects that can help the Seniors cope with their daily life.

**Discussions**

With the infusion of Design Thinking and Service Learning pedagogies into the course, module experience survey results (refer Table 4 below) have shown improvements across the board. This survey examines students perception of their learning experience and the improvement was seen in terms of Feedback and Materials which are the areas that are usually low in the scores as indicated in the table below.

This result also shows that a change in the T&L has allowed for more interactions between the students and also encouraged students to be thinkers and learners rather than just passive recipients of knowledge. More significantly, the use of Design Thinking and Service Learning have not dilute the content that is being taught as students have indicated that their understanding of the content has not reduced instead the quality of feedback and materials have improved. This indicates that students are taking more ownership of their learning and are using the opportunity provided by the Design Thinking and Service Learning processes to be more engaged in their learning through discussions and consultations ingwith lecturers rather than just be passive listeners in the lecturer theatre.

Another benefit of infusing Service Learning into our course curriculum is the opportunity for our students to interact with a segment of the Singapore population which is projected to increase over the next few years, i.e. those aged 65 years old and above, and living alone. According to The Straits Times [7], Singapore's national English newspaper publication, this segment grew from 19.2% in 2000 to 31.3% in 2014 and is projected to grow over the next few years.

**Table 4: NP Module Experience Survey: CEM**

The seven survey questions are shown in the Appendix (A). In addition, students’ feedback has mainly been positive. They found that design thinking gives them a sense of purpose when they develop their projects. Some students’ non quantitative feedback is listed in the Appendix (B).

**Conclusions**

The need for a flexible learning design in curriculum delivery has been well documented.[6] Student feedback from these new blended learning models has been mainly positive. However an appropriate level of blending of the traditional classroom-workshop based learning model and newer pedagogies is essential for effective learning to take place in the 21st century. Finding a good balance will always be a challenge as...
technology changes have brought about a huge change in the availability of content for learning any time any place. Infusing Design Thinking and Service Learning philosophy into the curriculum are just small steps taken in response to the changing education landscape and thinking, the course curriculum must remain flexible and relevant to the changing expectations of the learners and the industry. The new curriculum design encourages students to take ownership of their learning and enables students to make connections between different modules. Students are also more aware of how their content knowledge is applicable in the real world and the impact it can have on the community.

Although it is early days, we are certain the infusion of the Design Thinking and Service Learning pedagogies into the curriculum will benefit our students and will bring about the desired learning outcomes in our graduates so that they are better equipped for their next learning journey and future career beyond the Polytechnic.

References


Appendix

A: NP Module Experience Survey Questions

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<thead>
<tr>
<th>Q</th>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>S&amp;K</td>
<td>The module helped me to develop useful skills and knowledge</td>
</tr>
<tr>
<td>Q2</td>
<td>Thinking</td>
<td>This module stretches my thinking</td>
</tr>
<tr>
<td>Q3</td>
<td>T&amp;L</td>
<td>The teaching and learning approaches are appropriate for this module/project</td>
</tr>
<tr>
<td>Q4</td>
<td>Feedback</td>
<td>I received useful feedback in a group/individually on my progress in this module/project/internship</td>
</tr>
<tr>
<td>Q5</td>
<td>Materials</td>
<td>The module materials (including materials on MyL and other online platforms) helped me understand</td>
</tr>
<tr>
<td>Q6</td>
<td>Activities</td>
<td>The module activities enhanced my overall learning experience</td>
</tr>
</tbody>
</table>

B: Samples of our students’ survey feedback.

I liked that we had a CEMP1 and CEMP 2 projects in our year 2 semester and it was a challenging experiences having to juggle with other modules and the project. I learned a lot during the project as we had to make our own system of our choice and connecting it with a stand-alone solar panel system. Improvements.

Practical work (site visits, learning more about electrical systems and renewable energy system in a practical way not just on theory.

Its well-rounded skills and knowledge acquired from different modules throughout the 3 years can be used in other modules.

So far the course has been an enjoyable experience and enjoyed it thoroughly.

We had interesting excursions to Siloso Beach Resort and other places.

The course is relevant to the current working world and the modules are good.

I like how our modules are mostly hand on which makes learning a lot more fun!

I get to be able to work on my very own project and have to come out with my own circuit.

Helps us to relate what we learn in class to practical use.

I was able to construct a project for a Resort.

This module helps me to understand how everything we study links together.

Being able to design our own circuit diagram.

This module exposes us to hands on experiments and we get to know better on what our course is about.

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