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International student outcomes of problem-based sustainability projects
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Abstract
This case study examines the strengths and weaknesses of a Problem-based learning project conducted at a New Zealand Institute of Technology by international students researching the process and effects of converting a petrol-powered three-wheeled motorised vehicle (Tuk-Tuk) into a battery-powered electric vehicle. Such unmodified vehicles are a significant cause of air pollution and allied social issues in third-world countries. Students were divided into two groups according to their study areas - the first group (two automotive students from Tanzania and Fiji) focused mainly on mechanical aspects of the conversion. The second group (three electrotechnology students from Saudi Arabia) designed the power system and explored the practicality of using solar energy to assist battery recharging. Both groups had specialist supervisors and were expected to collaborate with one another, but all students were asked to develop their own research questions and methodology, focussing on the wider rationale for sustainability within their discipline. The purpose of the current study is to examine the learning experiences of these international students who had participated in this collaborative, interdisciplinary, sustainable transport project. They were expected to undertake all aspects and challenges of a real-world project - theoretical research, design choices, purchasing decisions, dealing with components suppliers, as well as communicating with supervisors and industry bodies. In this process students demonstrated different levels of independence in learning and problem solving skills and the project had a significantly different impact on each student. At the end of the project feedback was sought from all the students on their learning, and the extent to which they thought it might influence their insights into sustainability and their career opportunities upon returning home. Their reflections, together with the responses from the two supervisors, have led to recommendations for future improvements in this form of pedagogy.

Keywords: Sustainability, Real-world project, International students, Scaffolding

Type of contribution: best practice paper

1 Introduction
This paper describes an investigation using PBL methods for facilitating sustainability with final year degree students many of whom are international.

The Bachelor of Applied Technology at Unitec Institute of Technology has been offered to students since 2004 and although it has been much re-constructed over the intervening years, it has always included the graduate capability of Sustainability in its professional outcomes. In other words, students emerging with this qualification are not only expected to be industry ready, they should also be aware of the significance of Sustainability as it relates to their profession, whether that is in electrotechnology, automotive engineering or marine design.
In a compulsory second-year course, Sustainable Technologies, students have previously been exposed to a range of innovative technologies connected to transport, pollution and energy generation, and have come to see that many technological developments, designed to benefit individuals or communities have frequently been accompanied by a range of negative effects. For a large proportion of our international students this is the first time they have encountered such ideas and for a few of them, this has made a significant impression (Panko & Sharma, 2014).

Out of this background came the concept of inviting two groups of international students to undertake Problem-based Sustainability learning for their final year project. With initial input from the automotive students, this developed into an investigation of the process and effects of converting a petrol-powered three-wheeled motorised vehicle (a Tuk-Tuk) into a battery-powered electric vehicle. Unmodified vehicles of this type are a significant cause of air pollution and allied social issues in third-world countries, especially in Tanzania where they are a widespread form of transport. It was anticipated that converting these vehicles from fossil fuel to electric power and enabling them to recharge efficiently in rural areas could introduce sustainability benefits to local communities, particularly in terms of health and economics.

2 Theoretical underpinning

Literature indicates that vocational students frequently have dismissive attitudes towards sustainability (Shephard, 2008; Torbjörnsson, Molin & Karlberg, 2011). Nevertheless, the United Nations Millennium Declaration (2000) emphasises that changing the values of people, especially from the technological sector, is vital if sustainable development is to be achieved and this can only happen through a process of transformative learning (Sterling, 2001). Sterling explains this as a paradigm shift, “which values, sustains and realises human potential in relation to the need to attain and sustain social, economic and ecological well-being, recognising that they must be part of the same dynamic” (Sterling, 2001:22). It is therefore hoped that substantial elements of this attribute have become more than mere knowledge of sustainability practices for our students, applicable to their varying industries. By examining examples from their home countries as well as undertaking practical investigations, a change in their affective domains – their values, attitudes and behaviours (Shephard, 2008) is sought through their programme of study. Obviously, the extent to which this is successful would be expected to vary from student to student.

Much has been written about the finer points of PBL and although there is no unanimous position about its precise characteristics, a number of basic principles of this learning process can be seen as constant (Table 1). Likewise, a number of different models have been promulgated, such as Hybrid PBL (Bessant et all, 2013) which Bessant and her colleagues have found effective in sustainability education. Some of the most generally accepted features have been identified by Nelson (2010) and are indicated briefly on Table 1. Similarly, features which demonstrate effective learning about sustainability, primarily through active engagement, have been analysed by Burns (2011) amongst others, and show many overlapping features with those highlighted by Nelson. In both cases these are designed to bring about transformative learning which Burns emphasises cannot be achieved through teacher-centred, transmissive models of education.

While our Industry Project case study relates to the main elements of PBL and transformative sustainability education, it does not fit neatly into the proposed formats. This is because it is a practical model and as such is an eclectic mix, varying in accordance with the context of discipline, learner and supervisor. However, within the Savin-Baden schema (2000) our project comes closest to her Model II – PBL for Professional Action, which is particularly relevant when we consider the role of the facilitator later in this paper.
Using these models, we have drawn links between the three elements of PBL, Sustainability and our Industry Project model, as indicated in Table 1. Nevertheless, as our course relied heavily on the students’ abilities to work independently, solving a number of ill-structured contextualised problems and then to see practical applications in their professional fields (Burns, 2011), a potential weakness became apparent. This weakness, earlier identified by Savin-Baden (2003), is the possibility of the development of a narrow set of skills which may not include cognitive content or professional judgement. This aspect is relevant to this study as Savin-Baden highlights that the role of the facilitator/supervisor is critical and that in order to develop increasing learner independence, scaffolding has to provide room for this to take place. This issue becomes increasingly significant when students come from a variety of international backgrounds, many unused to taking responsibility for their own learning. This was the prime motivation in the development of this case study as it is anticipated that improvements will be made to the delivery of our project as a result of our findings.

Table 1: A comparison between the principles of PBL, Sustainability teaching and the Industry Project course.

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<tr>
<td>Student-centred</td>
<td>Empowering learners to solve complex problems to sustain places and communities</td>
<td>Supervisors facilitate learners to solve problems &amp; relate to home country</td>
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<tr>
<td>Ill-structured contextualised problems</td>
<td>Content: Sustainability themes</td>
<td>Trial technical solutions – with a sustainability focus</td>
</tr>
<tr>
<td>A multi-disciplinary focus</td>
<td>Context: Place and crossdiscipline based</td>
<td>Discipline knowledge combined across groups</td>
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<tr>
<td>Self-regulation and collaboration</td>
<td>Process: Participatory and experiential</td>
<td>Experiential and collaborative</td>
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<td>Reflection and evaluation</td>
<td>Perspectives: Diverse critical questioning</td>
<td>Reflect on learning and seek affective learning outcomes.</td>
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<td>Closing analyses</td>
<td>Transformational learning</td>
<td>Future translation of sustainability project experience into action in an international context.</td>
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Making this process effective, in the eyes of both students and supervisors, for a diverse range of students has been analysed in detail by Kim and Hannafin (2011) who have identified five stages in the process of scaffolding practical PBL. These can be summed up as Problem: identification, exploration, reconstruction, presentation and reflection and when considered in detail, these stages allow supervisors to respond flexibly to the needs of different learners.
3 Project design

Students were divided into two groups according to their discipline areas – the first group (two automotive students from Tanzania and Fiji) focused mainly on the mechanical aspects of the conversion. The second group (three electrotechnology students from Saudi Arabia) designed the power system and explored the practicality of using solar panels attached to the roof of the Tuk-Tuk to assist battery recharging. The Industry Project was allocated one semester to complete, following a preliminary research proposal had been undertaken by the students in the previous semester.

This paper was initially intended to focus on the overall strengths and weaknesses of the Industry Project as an application of PBL, particularly in respect to Sustainability. However, the information gained caused us also to consider the diverse scaffolding requirements of the students as it became a significant issue in the study.

The approach we took comprised participant evaluation of the PBL project from the points of view of both supervisors as well as the five students involved. An observation record was also kept of the project as it unfolded and how students responded to the challenges of a real-world project – involving a combination of theoretical research, design choices, purchasing decisions, dealing with components suppliers, as well as communicating with supervisors and industry bodies. The primary motivation for the main part of the study is to improve the PBL experience, in particular for international students who are likely to be unaccustomed to this form of independent learning, as well as increasing the likelihood of subsequent sustainability uptake in their professional lives. Ellis, Cummings & Turner (2009) highlighted the increased engagement of international students when highly interactive PBL techniques were applied and revealed that their students subsequently produced high quality reports.

Once the practical work was completed, the reports completed and awarded a grade, semistructured interviews were carried out with each group separately, both students and their supervisors, in order to encourage open discussion. It is planned to attempt to continue this communication with the students once they have returned to their homes, via brief phone calls, to discover whether any long-term sustainability effects can be identified. After an initial flurry of meetings, the students settled down to meet with their supervisors approximately once a week, sometimes in small groups within their own study areas but frequently as a group of five with one or both supervisors.

Practical workshops with theoretical discussions (started at the second half of the semester) were the first real opportunity for the two groups to meet and get to know each other. At an early stage they also visited an industry group of electric vehicle enthusiasts where they saw a variety of somewhat eccentric forms of transport such as a single-wheeled motorbike and a car propelled by electricity produced from a wood-burning stove. Having seen examples of what could be achieved and the enthusiasm these projects generated, they collectively agreed to order a new petrol-powered Tuk-Tuk. Initially it was anticipated this could be obtained through Institute connections in India and several weeks passed without progress being made before the students took the initiative and placed an order with a Chinese supplier. At that point they decided to delay their purchase of a conversion kit until they had examined the vehicle and knew what would be suitable. They also postponed obtaining the solar panels for the same reason. These items eventually arrived a few weeks before the conclusion of the project.

Such extensive delays impacted the practical aspects of their project, particularly for the Saudi Arabian students exploring the alternative energy systems. In principle this required them to rely heavily on the theoretical aspects of their studies, with time to investigate in more depth the potential effects of transport
sustainability and pollution as well as energy supplies in their own countries. In practice they became highly concerned about obtaining a successful outcome and began to doubt whether they would pass the course — their ultimate goal. This unsurprising response reinforces Savin-Baden’s (2003) findings that learners were likely to react to difficulties in at least four distinct ways: retreat, temporising, avoidance or finally engagement, the first three being forms of resistance. To limit resistance and encourage engagement, a recent handbook supporting PBL facilitators (Fraser, 2015) stresses that instructors need to be most active in the early stage of development in order to facilitate a SMART project (Specific, Measurable, Achievable, Realistic and are able to fit the Timeframe).

Once the Tuk-Tuk was delivered, the students and the automotive supervisor met regularly at weekends, spending a full day each week collaborating on a series of mechanical and electrical tests — the results of which strongly reinforced the pollution effects of the Tuk-Tuk. They were encouraged to keep writing up their research and the electrotechnology students joined their class colleagues in arranging a demonstration of their project as part of their assessed work.

4 Findings

The findings described here were obtained primarily from four data sources: semi-structured interviews, observations (made by the first two authors during the study); students’ reports, and lastly, the results summary of the grades obtained by each of the five students. In addition to gaining participants overall responses to their experiences, we also concentrated on aspects of their learning processes such as collaboration, content learning and sustainability concepts.

4.1 Interviews

Three separate interviews took place, one with both supervisors, the second with the automotive students and the third with the electrotechnology students.

Firstly, the two supervisors considered that the projects had ultimately been successful but that the individual and cultural characteristics of the two groups caused the students to respond in different ways to their experiences. They largely agreed with each other’s evaluation of the students’ performance: that overall the projects had been challenging, engaging and had increased the capabilities of the undergraduates. Both supervisors explained that in this study, as in other classes they had facilitated, they had found Saudi Arabian learners to be pragmatic, non-risk takers focussing strongly on obtaining a good grade which they believed will lead them into satisfactory employment. One of this paper’s authors said, “My students enjoyed the challenges of a real-life project while for some of the other students, obstacles, such as time and resources, were very frustrating... they [the automotive students] come here with shiny eyes.” On the other hand, the other supervisor said, “The electrotechnology students were looking for the answer, rather than for the experience”.

They agreed that the automotive students appeared to be motivated by curiosity and ready to accept the challenges that real-world situations caused. All students remained on-task and kept returning to the workshop sessions. One of the supervisors emphasised that it was vital that all students should feel engaged with their particular topic and for this reason that it was important that topic choice be provided to enable this to occur.
Both supervisors noted that one of the automotive students had driven the project, had led the communication with the others and had developed a deep appreciation of both the sustainable and technical aspects of his work. Although this had been one of the reasons why the project had been successful, it also meant that some of the other team members were put into the position of ‘followers’ and therefore had less of an opportunity to initiate their own research.

In relation to assessment, the electrotechnology supervisor explained that his colleagues used a cross-moderation process where all grades were jointly considered. At that meeting the faculty had been impressed by the fact that the students were continuing to work on their project even after the reports had been handed in. Collaborative practical work, clearly of great significance in the Industry Project, was positively recognised during the assessment process but was not explicit in the marking schedule.

Supervisors confirmed that the students were aware that their projects were underpinned by Sustainability concepts and had focussed on aspects which related to their industries within their own countries. For example, although there are no Tuk-Tuks operating in Saudi Arabia, the students had seen opportunities for small electric vehicles of this type to be of great potential value during religious celebrations when many thousands of people required pollution-free transportation. One supervisor recommended that supervisors should always have a Plan B, such as the development of a small bench-top proof of concept. This could not only be a fallback strategy but at an earlier stage could help to conceptualise the sub-sections of the major project and provide confidence to the learners.

Secondly, when the two automotive students were interviewed, they emphasised the significance they gained by tangibly ‘doing’ the project. They stressed the value they discovered in team work and the benefits of working with a cross-cultural group, “Knowing how everyone behaves and how different cultures work. Because the marketplace today is not like the traditional workplace where you have your own people there only.” They explained that they had learnt how to enhance their communication skills to deal with industry suppliers, colleagues and supervisors. They had also developed an awareness of time management skills, coming to recognise that each person in a team works differently and for this to be successful, patience is often required. However, above everything else they kept returning to the depth of understanding they gained through their practical studies, “you talk about electric cars – it’s just a word but when you actually do it, you see how simplistic it is ... and how much you could do with it.”

They agreed that they had developed a different perception of the importance of sustainability and how and why they should struggle to achieve this in their day-to-day lives, especially where this is not happening in their home countries. One saw hope for Tanzania with the growing awareness of youth and he believed that the new generation of educated people would start to put sustainability concepts ‘into the system’. The other considered that the fields of energy and transport would be the ones to benefit most from sustainability innovation in Fiji. He explained that the government of Fiji supported this step and had already reduced import tax on electric vehicles from 15% to 0%. They recommended that all students taking the Bachelor of Applied Technology should have the opportunity to focus more on practical projects rather than producing reports with a mainly theoretical basis. They suggested the use of some form of 3-D modelling to develop scaled down prototypes relevant to their disciplines.
Thirdly, the three electrotechnology students focussed largely on the technical side of their project and the difficulties they experienced. They spoke about being advised at the start to read widely but that would be too confusing as it “brings to our minds too many ideas.” They commented on the delays they experienced and said that if they had realised the extent of the problems, they would have requested a different topic. “The main focus for us as students is to gain marks.” However, they agreed that even the difficulties enabled them to gain experiences that would help them in their professions – namely time management and ordering equipment “This is what huge companies and even countries face – delays and payment problems can be big issues.”

They spoke enthusiastically of the collaborative nature of the project, the value they found in working together as a group and with the automotive students. “On your own it would take more time and be more difficult.” “Within our own group some individuals may know more or be motivators – ‘don’t worry, I’ve got the solution.” They also said that some aspects of supervision had greatly helped them. For example, making the measurements they needed so that they could order the correct conversion kits.

In regard to the concept of sustainability they said that they had started from a position of unfamiliarity, first meeting the concept in their earlier course, ‘Sustainable Technologies’.

In our own country, the focus we have is oil and as Saudis we want to change that. We can make solar panels and electric vehicles which can benefit the country and decrease pollution because an electric car makes a friendly environment.

They considered that there were many opportunities for alternative energy in Saudi Arabia, due to that country’s high levels of sunshine and explained they were hoping to pursue these prospects once employed in industry.

Their biggest concern concerned the role they saw their supervisor had played. Although they acknowledged he had forced them to think deeply and explain all their decisions they felt he had largely ignored them. They were distressed he had not held regular weekly meetings and had delayed responding to their emails when they sought either answers to their problems or feedback to their work. They concluded by wishing they had been able to have more input into their choice of project and that the assessment scheme could have more accurately acknowledged the effort they had put in.

4.2 Workshop observations

The following observations of learning experiences were made by an automotive lecturer who was initially supposed to supervise the automotive students only in mechanical aspects of the conversion process. After the electrotechnology students expressed their wish to participate in the mechanical part of the conversion, two groups were set to work as a team. The team building meetings failed at the beginning as the automotive students became very sceptical about the knowledge and capabilities of electrotechnology students, one of them even expressing serious doubts about productivity and prospects of such team work. It put the already distressed electrotechnology students in a defensive mood, diminishing the required collaboration.
Initially, the supervisor tried to address this additional challenge in a formal way by reminding that they all (including the supervisor himself) were largely learners in this conversion process. Later, another more efficient approach was found - the supervisor would allocate additional time to initiate and to maintain an informal conversation within the team on seemingly irrelevant but engaging topics: national cuisines and sports, students’ hobbies and their home countries’ lifestyles, traditions, cultural practices, etc. Such conversations (prior to the workshops and during lunch and tea breaks) significantly reduced the initial psychological barrier between two groups. The automotive students even began to provide peer supervision in the mechanical part of the conversion for their less experienced electrotechnology colleagues. Later, when interviewed, the automotive students recognised the challenge and the value of working in a cross-cultural team, admitting also that it helped to enhance their communication skills and to practice their patience.

The electrotechnology students appeared to be diligent, earnest and reliable learners, but reluctant to show their knowledge and to demonstrate capabilities. They were curious and fairly engaged in the practical process, but rather cautious in challenging the status quo of technology - the necessary step in this conversion process. They showed their ability to be reasonably independent learners but it required some additional guidance from the supervisor and efforts in terms of workshop planning and structuring. With these supports the electrotechnology students, for example, were quite successful in evaluating fuel consumption, tailpipe exhaust and noise emissions of the unmodified Tuk-Tuk and were able not only to explore and to reconstruct the problem but also to reflect on their learning experiences.

The automotive students were eager to learn from the conversion process and were highly motivated by prospects to see and to test the final product of such conversion. They came into the project with a good level of theoretical knowledge and considerable practical experience in repairing cars and trucks, also having some initial perception of ‘simplicity’ for the conversion process. This attitude changed very quickly, as from the very beginning it became obvious that the conversion process, by comparison with vehicle servicing/repair, was not a standardised process defined by the manufacturer in a workshop manual. For example, the ordered conversion kit (the rear axle with an electric motor) did not have the right dimensions, so the students with the supervisor had to manufacture additional components and to revise the installation principles.

It was even more challenging, since all money from the research grant was spent for purchasing/shipping the Tuk-Tuk and the conversion kit. This shortage of funding had also a surprisingly positive effect on learning experiences – instead of ordering expensive components from third party suppliers, they were made in-house by the research team. Many of those components received an elegant, simple yet effective design and were made from scrap metal, thus giving another dimension of sustainability for this project.

The automotive students, as independent learners, responded to those challenges by demonstrating high level of non-standard and creative thinking, problem solving and interpersonal skills. As a result, the first stage of the Tuk-Tuk conversion process (without the installation of the solar recharging system) was completed successfully.

### 4.3 Results and Reports

All five students produced individual reports and after assessment and moderation all five passed, both automotive students gaining A+ while the electrotechnology students each received B+.

The automotive reports were wide-ranging, examining a number of aspects of sustainable transport in their home countries and provided extensive literature on the nature of problems and their possible solutions. The practical investigation of the Tuk-Tuk, such as its production of environmental pollutants, high noise
emission and ineffective levels of fuel consumption only occupied approximately a quarter of the completed reports. The conversion of the fossil-fuelled Tuk-Tuk to a vehicle with an electric motor served primarily as a practical example of energy conservation. The value of encouraging solar power to be used as a mechanism to charge these vehicles was considered from the standpoint of how it could improve the lives of rural populations.

On the other hand, the electrotechnology students concentrated on the data achieved from the Tuk-Tuk investigation and provided detailed descriptions of the technology involved in such a conversion. Although brief mention was made of electric vehicles in relation to sustainability, this was not examined in any depth.

5 Discussion and Recommendations

For all students, regardless of nationality, the Industry Project successfully encouraged the PBL values of student centeredness, multi-disciplinary focus, self-regulation and collaboration highlighted by Nelson (2010). This empowered them to tackle complex problems with a sustainability theme and potentially provided a transformative learning experience.

All students worked enthusiastically to solve complex cross-disciplinary issues and attempted to consider them in the light of sustainability, to a greater or lesser extent. Where this aspect was weak, further guidance from supervisors could have been a remediating factor. This leads to the question of the extent of assistance that might be needed, when the demands of supporting inexperienced international students might conflict with the need to let them develop their own solutions. This issue has been discussed by Kim and Hannafin (2011) within the concept of scaffolding and appears to be particularly appropriate when responding to the needs of international learners. These authors demonstrate that it is totally legitimate to provide additional guidance at any stage of the project that may be posing difficulties. Often this will be in the opening stage when project identification and engagement is occurring and also towards the conclusion when the projects are being presented, an especially difficult time for non-English speakers. Additional scaffolding during the identification and explorations stages would allow students to refocus on their sustainability goals, especially about the potential impact of their projects in their home countries.

Although it would be unsafe to generalise from such a small case study, some issues relating to international students and PBL did emerge, which appeared to be corroborated by lecturers’ experiences beyond this investigation. These confirmed the expectation that international students are likely to start PBL without prior experience of many of the fundamental principles of independent learning and the ‘what if?’ mode of creative thinking. This relates to Burn’s (2011) concepts of encouraging critical questioning.

A number of enhancements to this course have emerged during this case study which might help to improve its outcomes can be summarised as follows:

- Support diverse needs of international learners by selective scaffolding (Kim and Hannafin, 2011).
- Provide active guidance in the early stages (Fraser, 2015).
- Clarify the assessment process so that learners are motivated to develop wide cognitive competency (Savin-Baden, 2003).
- Encourage the development of a ‘back-up’ plan to increase confidence and to ensure that lack of resources does not inhibit project success.
6 Conclusion

It is hard to conceive of any PBL model that could support the needs of every learner, considering the distinctions that are introduced through the diversity of international students and supervisors’ different methods of stimulating learner independence. As Savin-Baden points out, “students’ own agenda and their reasons for ‘being learners’ at a particular point in their lives, can affect to a large extent their expectation of, and response to, the kinds of learning on offer.” (2000: 145)

Nevertheless, our observation from this case study show that facilitators do need to recognise that these differences exist and scaffold their support within these parameters.

In order to further this Best Practice study, observations could be extended with a larger number of students and information could be sought about the impact such PBL experiences have upon their subsequent professional lives in regard to both the scaffolding they might require to encourage their learning autonomy as well as a deeper awareness of sustainability?

References


