

Early Engineering of Professionalism through Service-learning: Engineering Projects in Community Service, Internationalization and Professional Societies

Abstract

There has been a shift in the acceptance of community engagement and service-learning, as a pedagogical tool, in the fields of engineering, engineering technology and the built environment. This article discusses an Engineering Projects in Community Service (EPICS)-in-IEEE project implemented at the University of Johannesburg (UJ) through the Faculty of Engineering and the Built Environment and shares best practices and lessons learned as the program developed. As EPICS-in-IEEE requires, the partners included UJ students and faculty members, a non-governmental organization (NGO), Engineers without Borders-UJ, and secondary school learners (the pre-university component) from UJ Metropolitan Academy. The EPICS-in-IEEE technical design and development phase was constituted and used as a guideline. The results of this project demonstrated at least five positive implications. University final year/capstone engineering design projects and exit-level outcomes were achieved. Participants worked as a team on engineering-related projects for a local NGO and its community. The project prepared engineering graduates for the professional world. Through the “social innovation” EPICS-in-IEEE concept, the initiative took the engineering, engineering technology and built environment disciplines to the community, instilled the UJ value system and achieved technical/professional outcomes in preparing students for careers in the private, public and non-profit sectors.

Key words: EPICS-in-IEEE; vertical integration; workplace culture; social innovation; service learning; professional development; engineering education.

INTRODUCTION

There is growing evidence that community engagement can be a powerful tool in breaking traditional engineering stereotypes and in academic programming that is more inclusive of marginalized groups: women and historically disadvantaged students. Sufficient evidence points to how these experiences prepare students for multi-disciplinary careers in the private, public and non-profit sectors.

designing

Accreditation bodies internationally have recognized the need to ensure that engineering, engineering technology and built environment graduates have a strong technical foundation, as well as a broad set of professional skills to contribute to and lead in today's global economy. Taking into account recent revisions to the accreditation criteria and indications from industry of what engineering graduates actually need, previous research shows that these demands are not likely to be achieved by using the traditional engineering curriculum, i.e. chalkboard learning pedagogy (Solorio et al., 2013).

Engineering educators at universities throughout the world are challenged to review curricula continually to prepare students to succeed in the ever-changing professional world. Universities are under pressure to produce graduates who can deal with short-, medium- and long-term societal challenges in a more relevant way. The relevance component has often required universities to graduate students whose skills are locally relevant, yet internationally competitive. Technologies will always change, therefore developing students' ability for life-long learning is much more necessary today than previously. In addition to technical expertise, the industry requires graduates to have both "hard technical skills" and a wide set of professional aptitudes, including communication skills, teamwork and leadership, global awareness, entrepreneurship and innovation. It was found that by modeling practical tasks, students developed an intuitive feel for electrical engineering parameters. Further benefits show that this allows engineering students to design or shape the world in which they live and in which they will eventually work (Kotze et al., 2017). Therefore, in order to improve the preparedness of engineering graduates for the professional world, learning programs that prioritize engineering design need to be applied. At this point, there are insufficient data to show how such programs (Engineering Projects in Community Service - EPICS) would directly prepare engineering graduates for the professional world, although anecdotal experience is promising.

Brief History

In 2010 the IEEE adopted its tag-line: "advancing technology for humanity." Given the IEEE's expertise in the technology space, in order to realize this tag-line it needs to partner with outside organizations that are championing ~~in~~ the humanitarian space (<https://www.ieee.org/about/index.html>). In 2009, the IEEE piloted the EPICS initiative through its geographical units (geo-units). The EPICS model, introduced by Purdue University, demonstrates vertical integration between various academic tiers at pre-university, university and post-university (alumni) levels. The IEEE took forward this concept developed by Purdue

University, namely EPICS, and under the leadership of volunteers Prof Kapil Dandekar (Drexel University) and Prof Saurabh Sinha (University of Johannesburg - UJ), the program continues to expand throughout the world, including South Africa. Although at present they are not directly involved, Prof Sinha is the current chair of the fund-raising working group for EPICS-in-IEEE (at a global level). The program is administered through one of the major IEEE boards, Educational Activities. EPICS-in-IEEE, which was conceived and championed by IEEE 2007 president Prof Leah Jamieson, is a program that organizes university and secondary school students to work on engineering-related projects for local humanitarian organizations or non-governmental organizations (NGOs). The purpose of the EPICS-in-IEEE program is to incorporate EPICS further into IEEE worldwide, by empowering student branches and IEEE gold groups to work with secondary school students on EPICS community service-related engineering projects, and by further institutionalizing the program within IEEE. Projects that are within IEEE's fields of interest should address one or more areas of interest in education, access and abilities, human services and the environment (http://www.ieee.org/education_careers/education/preuniversity/epics_high.html).

To date more than 51 projects have been launched in 71 different countries, involving over 204 volunteers, with 427 university students and 800 pre-university students making an impact on 90 000 people in communities around the world. In South Africa (region 8) alone at least six EPICS-in-IEEE projects have been successfully completed (Pretoria, Durban and Cape Town).

Research Aims

This study sought to examine the effect of an EPICS-in-IEEE project on engineering students at UJ. This paper demonstrates how such an initiative prepared engineering students for the workplace. It examines the impact that group design projects have on engineering students when there are changes in their social cognitive processes and “engineering education” development for university students while achieving exit-level outcomes (ELOs) in line with statutory body accreditation or graduate attributes relating to professionalism (Atadero et al., 2014). In South Africa, programs are accredited through the Engineering Council of South Africa (ECSA). This paper thus refers to ECSA ELOs. (refer to website)

Initiative Framework

Through its volunteers, the IEEE geo-unit identifies a non-profit organization (NPO) that has undertaken a project involving appropriate engineering content for its student participants. In addition, the geo-unit will reach out to educators from secondary schools willing to allow their

students to take part in the EPICS program and will mentor the secondary school students to pursue humanitarian projects. Figure 1 explains the various parties constituting an EPICS-in-IEEE project initiative.

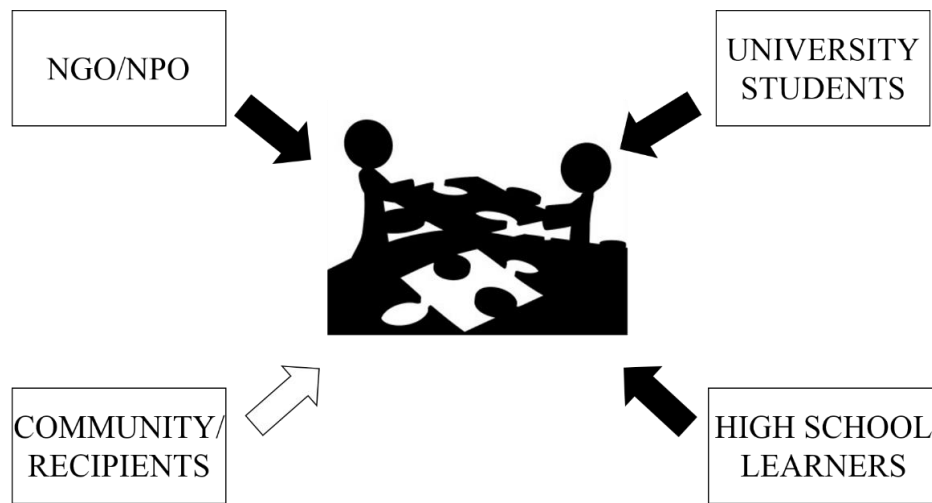


Figure 1. Various parties constituting an EPICS-in-IEEE project initiative.

EPICS-in-IEEE projects promote multi-disciplinary partnerships. In the context of emerging economies, where smaller municipalities are usually challenged by under-capacity, the partnership could include local municipalities.

Participants

Eight university engineering students (three females, five males) who are Engineers without Borders-UJ (EWB-UJ) members, 11 secondary school learners (50% female), one IEEE graduate student member, who is also a faculty member, and one educator (female Science teacher from a secondary school) participated in this project. This project was an extra-curricular activity for the learners. In this case, the secondary school partner was the UJ Metropolitan Academy, which is hosted through the Faculty of Education, UJ. The IEEE Eta Kappa Nu (IEEE-HKN), Lambda Psi, the only one of its kind in Africa, which has been established at the UJ, South Africa, served as the supporting IEEE entity.

METHODOLOGY

This section describes the study of and the integration approach used to articulate the central notion through exemplifying a particular EPICS-in-IEEE project. For simplicity in demonstrating project principles, a light project that would reduce the number of fires in the informal settlement of Kathrada Park was selected.

The EPICS-in-IEEE technical design and development phase constituted the following phases:

- Project identification/initiation
- Development of specifications
- Conceptual design
- Detailed design
- Delivery
- Service and maintenance.

Initiation

The goal was to identify a specific, compelling need to be addressed. To meet that goal, it was important to understand the need that the students were required to help address, and to start interpreting the need expressed by the project partner into acceptable and particular prerequisites that would aid the configuration. Such engagement develops project ownership upon transfer and is a prerequisite for success through enticement to complete the work.

In this service-learning initiative, EWB-UJ, an NGO made up of engineering students, came forward with a project statement. Kathrada Park, a community based in Claremont, Johannesburg, is an informal settlement where fractions of the poorest of Johannesburg's population reside. When the community was visited, several problems were identified. The selected project to be developed concerned a ^{solar} light (sun in a bottle) project. Given the challenges of connecting the community to electrical power, the light project would reduce the number of fires by introducing an alternative to candles or paraffin-based options.

The Liter of Light initiative was developed by Brazilian Alfredo Moser in 2002. The approach was initially launched in the Philippines by Illac Diaz under the My Shelter Foundation in April 2011 (https://en.wikipedia.org/wiki/Liter_of_Light). This Liter of Light initiative seemed a perfect solution for the lighting problem identified at Kathrada Park. While the project is simple, it demonstrates various aspects of multi-disciplinary systems engineering and teamwork, which can be seen below in Figure 2.

The concept involves the use of a 2L plastic bottle to refract sunlight inside a structure and serve as a solar lamp.



Figure 2. Teamwork component of this EPICS initiative: (top left) high school learners working on their section of the project under the supervision of an engineering student, (top right) the NGO along with engineering students on final delivery on site, (bottom right) IEEE graduate student member and NGO weekly/monthly meetings and (bottom left) engineering students working on their section of the project.

Specifications

Specifications in EPICS-in-IEEE are formulated to understand what the community partner needs, and by the end of the phase, to create measurable criteria through which design ideas can be assessed. This is accomplished by understanding the context, stakeholders, necessities of the project and the reason current results do not satisfy the need.

The plan in this case was to implement the Liter of Light solution, but catering for all hours of the day. It would also be necessary to conduct workshops to train the Kathrada Park community to design, develop and service these Liter of Light solar glass bottle bulbs. The partnership approach allowed for project sustainability through both the community and the NGO.

Conceptual Design

The conceptual design phase entailed brainstorming a variety of approaches in order to select the “best solution” to move forward. In this phase, it was essential to determine whether the project would meet the needs; this was a problem definition/re-definition phase.

The approach to this project, as the name implies “Light (sun in a bottle) for the informal settlement of Kathrada Park”, is basically using a glass bottle filled with water and suspended from the roof of a shack. Liter of Light is a global movement whose aim is ecological sustainability and a cost-free solution for interior lighting for informal settlement homes. During the day, sunlight strikes the bottle and owing to reflection and refraction of light as it goes through a change of medium, from air to water, light rays are scattered evenly throughout the inside of the shack, shedding sufficient light during the day. For the night solution, a small solar cell is fixed to the top of the bottle. This solar cell is connected to a circuit that charges a rechargeable battery. The rechargeable battery powers small numbers of light-emitting diodes (LEDs) that are fitted inside the bottle. At night, a mere flick of a switch is required to make the LEDs, with the aid of the refraction property of the water, yield enough intensity of light to illuminate the shack. The system can be assembled with or without the bottle, depending on the installation requirements or disadvantages in this regard to the household itself. A universal serial bus (USB) port is also installed for fulfilling another related, but essential need, namely charging a cell phone or other low-voltage direct current (DC) devices.

For a detailed explanation call us

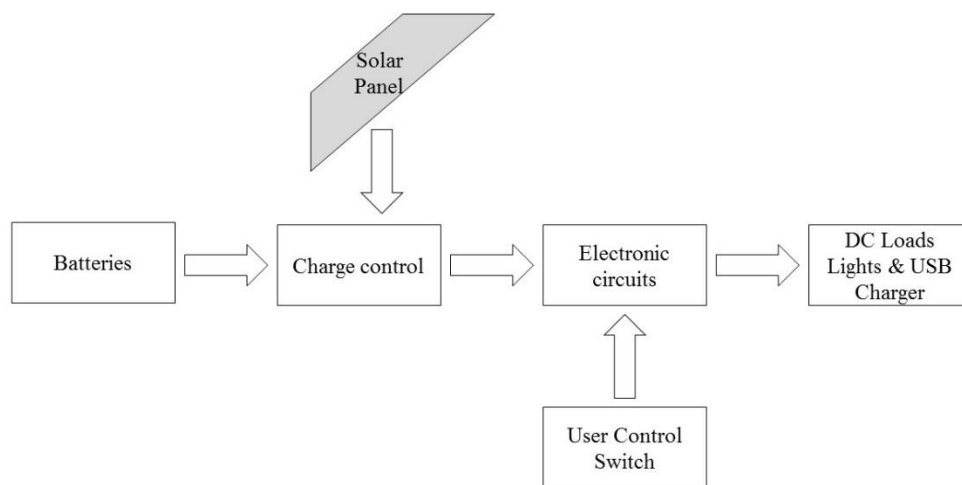


Figure 3. Block diagram.

Detailed Design

The goal of this phase is to design a working prototype that meets the technical specifications. The objective is not merely to check off tasks or answer questions; instead tasks and questions need to be utilized to ensure that the subsystems can be successfully integrated, that the design performs as expected and that it meets usability criteria. Throughout this process, it is possible

that the design specifications will be refined as knowledge is gained and a particular solution strategy is implemented. Some of the tasks are iterated (e.g. prototypes, testing, usability testing, failure), refining the technical solution.

A unique component of design and development was undertaken by the university students as well as the secondary school learners (who were mentored by the university students).

Before the undertaking, the learners had carried out their section of the project; the university students had set up workshops/Saturday classes for the secondary school learners at the university's engineering laboratories. The aim of the workshop was to familiarize secondary school learners with some of the electrical/electronic components used in manufacturing the Liter of Light project and basic skills training: assembling and soldering techniques.

If each circuit design and team component should be discussed separately (i.e. (i) Engineering students, (ii) High school learners and (iii) Completed project and delivery by NGO), the systems engineering and student/graduate relationship can be described as follows:

- Engineering students at the university, together with facilitators, designed an electrical/electronic system to charge batteries from solar energy, which in turn drove the relevant circuitry to turn on LEDs and charge low-voltage devices. These outputs could be turned on/off at will by the user, depending on the energy stored from solar energy. The university students designed the circuit and implemented it to work with its outer casing/jar. Figure 4 illustrates an initial phase of the solar-powered lighting circuitry.

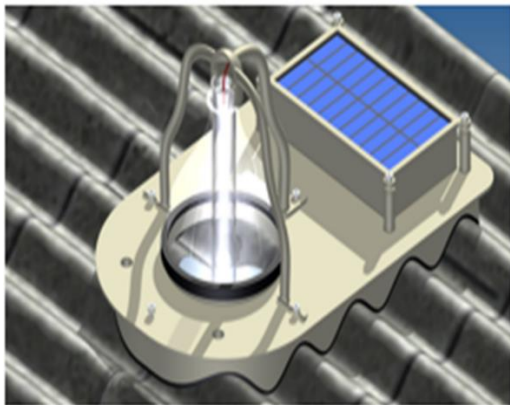
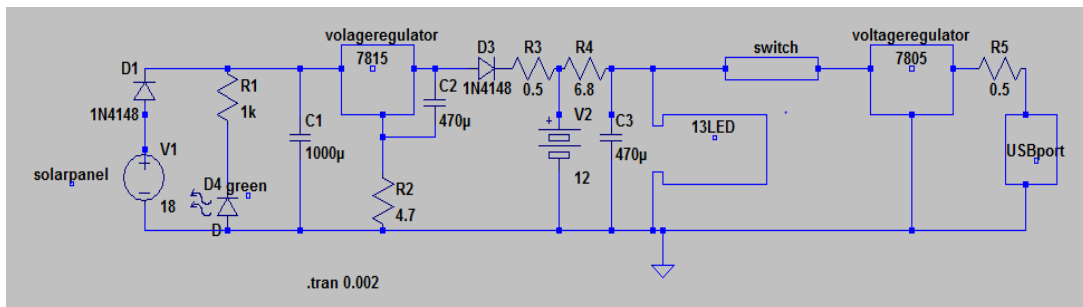
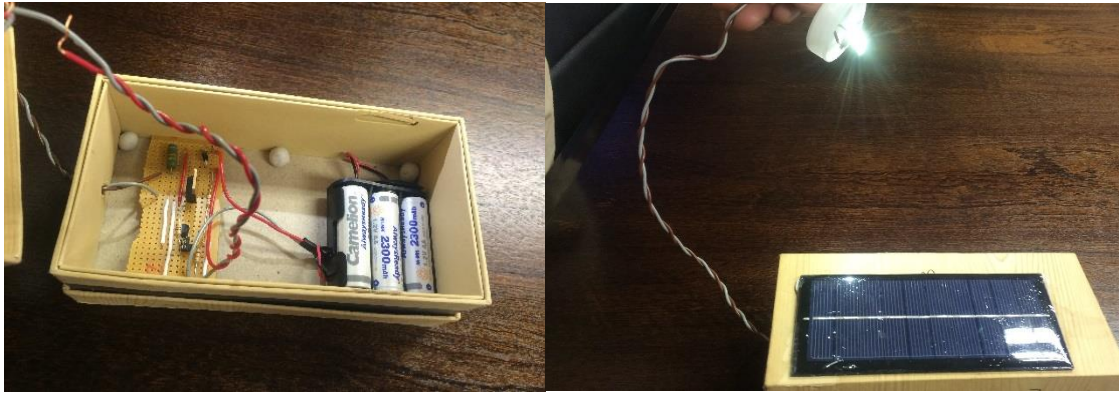


Figure 4. Early stages of the project depicting the above design.

- Together with a suitable secondary school educator, engineering students and 11 technically ready secondary school learners, the jar/outer casings and the electrical/electronic components were assembled under the university students' guidance. All equipment was supplied, along with the necessary instructions (user's manual). The secondary school learners mounted the ready-made solar panel cut-outs on the jar/outer casing tops, including assembly of the university students' completed circuit boards on the inside of the jar/outer casing tops. As shown in Figure 5, the learners were given the freedom to come up with creative ideas and inputs where required.



Figure 5. High school learners working on their section and simulating an informal settlement home.

- Final tests were done on the completed project/prototype so that the community could have a working product. Field test prototype/usability testing was done and all boxes were quality-assured. This step was taken in the next phase before the products were delivered to the community.

Delivery

The main goal was to end up with a successful, working project that was ready for delivery to the partner, i.e. the NGO/NPO, on time. Project delivery involved the NGO and the associated community after the following requirements had been satisfied:

- Approval from the partner and university supervisors, in order to make sure that the project was working and was safe for community deployment;
- Complete reports, user and training manuals; and
- Complete usability and reliability testing.

Completion of the UJ project with all relevant tests and documentation was important in this case, as this project served as a final year/capstone project. It was then handed to the NGO (EWB-UJ), which was made up of some of the university engineering students, who in turn coordinated project fitment. The secondary school learners were invited to join in project delivery as an extracurricular activity. Figure 6 shows all the project team members with the final design.



Figure 6. All the project team members with the final design

Maintenance

Since EPICS-in-IEEE serves the community, does the project end at delivery? Do we forget about the community served and move on to another challenge? EPICS-in-IEEE entails on-going evaluation and support from the team while it is in the field. Each semester the team should do maintenance and determine if the project should remain in the field or should be retired. Through NGO/geo-unit partnership, teams may evolve with different students, as students graduate, but with the view of sustaining the relationship with the community.

Since EWB-UJ is made up of university engineering students, they always interact with the community and have the knowledge to carry out any maintenance. They have taken this initiative one step further by training selected community members with regard to the project. The selected candidates were trained on how to operate the project and to deal with service or related needs. This offers the users self-sustainability and, in the medium term, transfers ownership to the community.

FINANCE

Deadlines, project hurdles and sufficient resources make projects challenging. From design to a working prototype, a large number of students find themselves facing unique “real-life” challenges (<https://www.mancosa.co.za/course/project-financial-management/>). As financing

is managed through the complex procurement system of the university, students gain better understanding of corporate financial management aspects.

It is therefore critically important for the project's success that students familiarize themselves with these tools in this efficiency-driven environment.

Through the Lambda Psi Chapter, the student leader (the primary author) applied for an EPICS-in-IEEE grant. The agreed amount sponsored by IEEE Educational Activities for this project was US\$5 000. The funding was transferred to the IEEE South Africa Section, which set up a memorandum of agreement with UJ. The project manager and team were empowered to manage funds directly for this EPICS-in-IEEE initiative, as well as to procure all the necessary items needed for construction and installation. Besides the component and installation-based approach, there were a number of other aspects for which the finance was used, such as reporting/publications, marketing, transportation and learning material for workshops with university students and secondary school learners. Financial breakdown and progress reports were also sent to the sponsor on a regular basis.

RESULTS AND OUTCOMES

Engineering Education

Students and learners, through teamwork, gained understanding of engineering and innovation, not only in project design and planning, but also human-centered design skills. They had to develop understanding and appreciation of the budgets stipulated by the stakeholders. EPICS served as a bridge for engineering students from education to practice and as an important means of gaining workplace experience. Most importantly, a working energy-efficient lighting system for the community was developed and the community was sufficiently trained to make implementation of the project self-sustainable. Students also developed better understanding of the social implications of technology, involving both unintended and expected consequences.

One of the key performance indicators of the university is the number of hours of community service. The university intends to deliver world-class citizens. By implementing a service-learning component in engineering education, the university is able to enhance its community contribution.

Since the EWB-UJ organization in this EPICS-in-IEEE project is mainly made up of engineering students, university final year/capstone engineering design projects, ECSA exit

level outcomes for engineering students are achieved, and the specific ELOs can be related in Table 1 (https://www.ecsa.co.za/education/EducationDocs/E-02-PE_Whole_Qualification_Standard_r4.pdf):

Table 1. Exit-level outcomes that can be assessed through this initiative.

<p>“Exit-level Outcome 7: Sustainability and impact of engineering activity - Demonstrate critical awareness of the sustainability and impact of engineering activity on the social, industrial and physical environment.”</p>	<p>“Range Statement: The combination of social, workplace (industrial) and physical environmental factors must be appropriate to the discipline or other designation of the qualification. Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: health, safety and environmental protection; risk assessment and management and the impacts of engineering activity: economic, social, cultural, environmental and sustainability.”</p>	<p>The In this project: Given the context of South Africa, striving for sociocultural equality is necessary. Through this project, students were exposed to real-life systems engineering endeavor, which exposed them to concepts of sustainability – from a perspective of renewable energy, but also the realization that projects will require maintenance, and therefore local communities must be empowered to do this.</p>
<p>“Exit-level Outcome 8: Individual, team and multidisciplinary working - Demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments.”</p>	<p>“Range Statement: Multi-disciplinary tasks require co-operation across at least one disciplinary boundary. Co-operating disciplines may be engineering disciplines with different fundamental bases other than that of the program or may be outside engineering.”</p>	<p>The In this project: This EPICS-in-IEEE project promotes multi-disciplinary partnerships, in this case between NGOs, university students and high school learners (male and female). Specific technical and organizational</p>

responsibilities were allocated between these teams and quality assessment was carried out for each component completed; this made the design and completion unique to each team.

<p>“Exit-level Outcome 11: “Range Statement: Basic Engineering management: techniques from economics, Demonstrate knowledge business management; project and understanding of management applied to one’s engineering management own work, as a member and principles and economic leader in a team, to manage decision-making.” projects and in multidisciplinary environments.”</p>	<p>In this project: Engineering management brought together the technological problem-solving expertise of engineering students and the organizational, administrative, planning and financial abilities of management (led by a postgraduate student) as a result of them overseeing complex corporate processes (of a large university) from conception to project delivery and integration.</p>
--	---

Graduate attributes include:

- Professional and technical communication; sustainability and impact of engineering activity;
- Individual, team and multidisciplinary working;
- Engineering professionalism;
- Independent learning ability; workplace practices (technology programs); and

- Engineering management (engineering science programs).

The Scholarship of Teaching and Learning

Academics in South Africa, as elsewhere, are required to demonstrate excellence in teaching and learning through disciplinary scholarship.

The Johannesburg Institute for Advanced Study (JIAS) is a residential institute for advanced study, which is located on a separate campus in Johannesburg. Launched in May 2015, JIAS is a joint initiative of the UJ and the Nanyang Technological University, Singapore. The institute is governed by a council that comprises senior representatives of both institutions and six respected scientists, three nominated by each university. Through JIAS, follow-up scholarship of teaching and learning activities promoting the interaction between “society and technology” will be pursued (<http://www.uj.ac.za/faculties/humanities/JIAS/Pages/About-Us.aspx>).

A number of models for integrating engineering in the community were investigated, and allow for appropriate contextualization and assessment of the impact of teaching, learning, research and social innovation, decolonization, but most importantly serving the community with a renewable scheme as a source of electricity (Hoosain, 2017). The impact outcome can be seen in an online article by the IEEE (<http://epics.ieee.org/sun-in-a-bottle/>).

Further research is being done with another EPICS-in-IEEE project at the university, where a PhD candidate electrical engineering student is developing an insect monitoring system for plant protection. This partnership involves a local high school in Mpumalanga, South Africa, the perfect area where farming is the predominant activity.

CONCLUSION

With technology for humanity in mind, there is room for vast improvement in engineering pedagogy in emerging countries, whether in the tertiary or working environments. South Africa is trying to emerge from differences created by the legacy of apartheid. In this regard, UJ makes an immense contribution, as it accepts students from the widest diversity that the country offers. These graduates are transformed into individuals who in turn change the country; they frequently and quickly take up senior management positions. The individuals, however, at times get disconnected from their own areas of upbringing and this issue needs much attention. These areas are currently served by under-capacitated municipalities and NGOs. Expanding the EPICS-in-IEEE approach thus connects students early on to “real-world” engineering,

makes a positive impact on communities, develops and sustains partnerships and closes the loop on several ELOs that students need to attain in any case.

REFERENCES

- Atadero, R., Rambo-Hernandez, K. & Balgopal, M. 2014. Using social cognitive career theory to assess student outcomes of group design projects in statics. *Journal of Engineering Education*, 104(1): 55–73.
- ECSA.co.za. 2016. EducationDocs. [online] Available at: https://www.ecsa.co.za/education/EducationDocs/E-02-PE_Whole_Qualification_Standard_r4.pdf. Accessed 15 Feb. 2016.
- Huff, J., Zoltowski, C. & Oakes, W. 2015. Preparing engineers for the workplace through service learning: Perceptions of EPICS alumni. *Journal of Engineering Education*, 105(1): 43–69.
- Hoosain, M.S. 2017. Smart homes: Energy efficiency based on demand side management, demand response and artificial intelligence techniques. Unpublished MEng dissertation, University of Johannesburg, Johannesburg, South Africa.
- Ieee.org. (2016). IEEE about IEEE. [online] Available at: <https://www.ieee.org/about/index.html>. Accessed 14 Feb. 2016.
- Ieee.org. (2016). IEEE Engineering Projects in Community Service (EPICS) in IEEE. [online] Available at: http://www.ieee.org/education_careers/education/preuniversity/epics_high.html. Accessed 14 Feb. 2016.
- Kotze, H. & Spangenberg, E.D. Eliciting engineering diploma students' visualisation with techno - modelling tasks. *Scholarship of Teaching and Learning (Sotl) in the South Conference*. Johannesburg: Scholarship of Teaching and Learning (SoTL) in the South Conference, 2017. PP 1-10.. 1 Oct. 2017.
- Mancosa.co.za. (2016). Project financial management - MANCOSA. [online] Available at: <https://www.mancosa.co.za/course/project-financial-management/>. Accessed 15 Feb. 2016.
- Oakes, D. & Zoltowski, W.M.C. (2015). EPICS: Meeting outcomes with multidisciplinary student teams. In Canadian Engineering Education Association (CEEA15) Conf. McMaster University, May 31 – June 3, 2015. Proc. 2015: CEEA15. PP 1-10.

- Sharepoint.com. (n.d.). Epics_design_process. [online] Available at: https://sharepoint.ecn.purdue.edu/epics/teams/public%20documents/epics_design_process.pdf [Accessed 15 Feb. 2016].
- Solorio, C., Garcí 'a-Cue 'llar, A. and Flores, A. (2013). Design and Construction of a Boat Powered by Solar Energy with the Aid of Computational Tools*. *International Journal of Engineering Education*, 29(2), p.386.
- Sun in a bottle - EPICS In IEEE. *EPICS in IEEE*. N.p., 2017. Web. 25 Mar. 2017.
- Uj.ac.za. (2016). Johannesburg Institute for Advanced Study. [online] Available at: <http://www.uj.ac.za/faculties/humanities/JIAS/Pages/About-Us.aspx> Accessed 15 Feb. 2016.
- Wikipedia. (2016). Liter of Light. [online] Available at: https://en.wikipedia.org/wiki/Liter_of_Light Accessed 28 Mar. 2016.
- Zoltowski, C.B. & Oakes, W.C. (2014) Learning by doing: Reflections of the EPICS program. *International Journal for Service Learning in Engineering*, Special Edition, 1-32.