PROFESSIONAL LEARNING : A MULTI-DISCIPLINARY AND INDUSTRY PRACTICE PARTNERSHIP

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Abstract

A Global Smart City Performance Index that ranks the top 20 global smart cities in terms of their integration of Internet of Things (IoT) technologies and connected services across four key areas namely mobility, healthcare, public safety and productivity has Singapore emerging at the top of the ranking for 2017, as reported by Navin (2018). This paper posits that this is achieved in part with the educational and training programmes that are in place in the Republic to train such professionals. This paper describes the implementation, experiences and lessons learned of one such programme called the Specialist Diploma in Internet of Things (SDIoT) at a polytechnic in Singapore, which adopts Professional Learning (PL) practices such as industry case studies, industry projects, industry study tours as well as industry practitioner delivery in its programme. The role of industry is a key feature that will be elaborated. This paper also describes the adoption of multi-disciplinary collaborations in its curriculum as well as technology-assisted learning in the form of a mobile learning platform to complement the programme.

Keywords: *Professional Learning, Industry Engagement, Internet of Things, Smart Cities*

Introduction

Singapore has a Smart Nation programme that represents her journey of economic, business and public sector transformation where technologies such as the Internet of Things (IoT), data analytics, artificial intelligence (AI) are leveraged upon to transform herself into a smart city. A Smart Nation and Digital Government Group, GovTech was reported by Teo (2017), to have been formed to drive several of these national strategic initiatives. One such initiative is the Smart Nation Sensor Platform which is an island-wide network of IoT-connected sensors that facilitate data collection and sharing (across various government agencies) for which insights gathered from the data can contribute to innovative solutions that help improve the lives of its citizens.

As Singapore embarked on its Smart Nation initiatives, it was challenged with the ability to meet the demands of suitably trained ICT professionals as reported by Weizhen (2016). Since then, we have implemented a programme that is targeted at working professionals or adult learners in support of this demand. The design of the programme, specifically in the way it engages its students, considers the characteristics of adult as learners such as adult learners having experiences that are rich and which should be seen as an important learning resource, adult's orientations to learning being more problem centred than subject-centred and adults being more capable of self-direction as reported by Knowles (1990) and James (2013). These characteristics, in combination with the need to equip with skills that are industry relevant sees the application of an approach in the programme termed as Professional Learning (PL).

Professional Learning is defined as the development of professional capabilities through teaching and learning experiences and activities that integrate academic, discipline-specific and industry-referenced knowledge, skills and attitudes as reported in Lawson (2011) and Billett (2011). Specifically, professional learning, encompasses the skills, qualities and attributes required by industry, with students participating in industry-oriented processes by engaging in real industry issues which encourages deep learning and where industry partners can be engaged in the development and delivery (including evaluation) of the curriculum.

The literature on PL describes a number of main approaches, noting that the practice of these approaches are not mutually exclusive. These approaches include industry case studies, industry projects, industry study tours / seminars, industry practitioner delivery, industry simulation, industry mentoring, industry placement and industry competition. In our programme, the first 4 approaches listed have been adopted and their application are explained in this paper. Beyond the above, the adoption of technology assisted learning and other initiatives to support a professional learning programme is discussed, including the issues faced.

Curriculum Design

The professional learning programme that we have designed is named the Specialist Diploma in the Internet of Things (SDIoT). To fulfil the manpower needs in a field where technology is fast evolving and the use cases of IoT as applied in the context of smart cities is expanding rapidly, the training programme for working professional's needs to be as industry relevant as possible. Besides skills training to fulfil job roles in IoT or to increase the job prospects of participants, the qualification obtained is recognized in Singapore and could articulate to other paths of more advanced learning.

The key considerations in shaping the SDIoT in terms of the subject matter coverage, the teaching approach, and the engagement model include the following:

1) The requirement of a multi-disciplinary approach, as demanded of any professional who is to work effectively in IoT. IoT project teams will be composed of different professionals who have to work collaboratively in teams and each need to have knowledge beyond their own areas of expertise to be effective, as described in Shenna (2015). Multi-disciplinary in our case refers primarily to computer science and engineering subject matter and specifically to foundational modules. Hence the inclusion of modules such as "3D Printing Fundamentals", "Engineering Basic", "Systems and Programming Basics" and "Introductory Statistics and Analytics" in the SDIoT programme.
2) Industry-relevant skills is a critical and key feature intended of the programme. As such, industry case studies, industry projects are some of the professional learning approaches adopted. Adult learners tend to be more inductive than deductive reasoners i.e. learn better from cases or examples and their response to cases or problems have to be driven from the practices and processes as applied in industry. This is reported in Duncan (2018).
3) A hands-on or very practical engagement to the modules is essential. Clear efforts are also made to ensure that the hardware used are industry-edge devices such as waspmote or Bosch XDK 110 as compared to just the use of Raspberry Pi or Arduino per se. The same applies to the use of software such as the ThingWorx IoT platform for developing industrial IoT applications. Besides, after a long day at work for these working professionals, lecture-based learning per se, where a classroom tends to be more passive, hardly aligns with efforts to engage and motivate student learner's especially adult learners.
4) Industry practitioner delivery, whether in the modules or in the form of industry study tours or industry seminars is also a key part of the intended programme. However, this is not possible for all engagements in the programme. Yet every effort is made for faculty staff to be trained by industry practitioners and gather relevant industry-level experiences beforehand. The programme that support the latter is named the Industry Attachment Scheme (IAS) and is described briefly later.
5) Technology enhanced learning was another feature that was introduced to deepen the students engagement with learning beside formal face-to-face sessions. In addition, such platforms afford for peer learning. In the SDIoT's case, a mobile platform called ULeap affords students the opportunity to engage with a wider community of learners outside of their peers. U-Leap is described later in this paper as well.

The structure of SDIoT therefore consist of two Post-Diploma Certificates (PDC's), with each to be completed within a six month semester, offered after office hours. The first PDC consist of 5 modules and the second PDC consist of 2 modules. See Tables 1 and 2. For some of these modules, students may be granted exemption on the basis of Recognition of Prior Learning (RPL) given the profile of adult participants that apply into this programme.

Table 1. PDC in Fundamentals of IoT

Post-Diploma Certificate (PDC) in Fundamentals of Internet of Things (IoT)
1) 3D Printing Fundamentals
2) Engineering Basics
3) System and Programming Basics
4) Introductory Statistics and Analytics
5) Internet of Things (IoT) in Consumer Electronics, Health, Homes – A Case Study Approach

Table 2. PDC in Advanced Applications in IoT

Post-Diploma Certificate (PDC) in Advanced Applications in Internet of Things (IoT)
1) Internet of Things (IoT) in Cities, Industry, Business – A Case Study Approach
2) Design Thinking Capstone Project

Upon successful completion of the SDIoT, the students will be well equipped to design, build and test complete IoT solutions that comprise sensors, wireless network connections, data analytics and display/actuators and write the necessary control software. Driving these outcomes are the design of assessment components, modes and weights that are industry or practice driven, in keeping with the professional learning approach adopted.

The Practice of Professional Learning

1. Industry Case Studies

The use of case studies are not new and their application in education is widespread especially in the fields of management, public policy, social sciences, medicine, law and engineering, as described by Bowe (2011), Yadav (2010) and Sarah (2011). Within the context of a professional learning programme, we have incorporated industry case studies as they afford an engagement that is more experiential, where students learn by doing. They are encouraged to ask questions and make informed decisions. They will need to participate and collaborate as they would as professionals at work where they need to understand the facts of a case and the variables to be debated, grasp what is going right and what is going wrong, what are the goals and objectives of the case and develop an action plan based on industry practices and standards, optimizing where necessary, in deriving a solution. The nature of such forms of engagement in learning enhance the employability or career of the students.

In our Specialist Diploma, two of the modules namely “IoT in Consumer Electronics, Health, Homes” and “IoT in Cities, Industry, Business” are taught using the industry case study approach where carefully selected case scenarios that are drawn from the projects of industry partners are used. These modules build on the foundation of the 4 introductory modules, though lesson matter content will still be taught within the two modules. But in this case, the lessons will be driven by the intended outcomes of the case scenario.

For a recent cohort undertaking the module, “IoT in Consumer Electronics, Health, Homes”, students were engaged in discussion and in designing and solutioning activities for a case study related to the pest situation in Singapore, The module culminated in the development of various prototype(s) that demonstrate the different approaches students took to addressing the pest situation.

Case Study: Connected Mouse Trap
Background: Huiwen (2016)
Industry: Pest Control
Issue (In Brief):

- A company had wanted to improve their product offering and competitive advantage. They wanted to create an intelligent mousetrap that lets users know when the trap has caught a mouse, thus preventing the user from having to check the trap every day.
- In order to make this happen, the company needed a way to send signals from battery-powered traps to an email or mobile phone. Because the traps run on batteries, the company would need something low-powered but could still send a strong enough signal inside a building.

In the module, the students went through a few stages, starting with identifying/clarifying on the problem/opportunity. In this case:

- Each team was tasked to list down the possible business/operational challenges and address the “why” questions. For example, why is this company deciding to embark on a journey for a connected mousetrap? etc.
- Each team is also required to also think and estimate how much this particular problem would cost. They need to develop a Return of Investment (ROI) metrics and identify users, buyers and financiers.

Following from the above, the teams moved towards technical solutioning where they adopt industry informed processes or workflows for building IoT systems, such as that described in Fuller (2016). In this case, a 4 stage architecture is adopted in which the technical elements to be considered at each stage start with sensors and actuators to the internet gateway, then the edge IT processing systems and finally the data centre and the cloud. As expected, teams have competing views and proposed different solutions to the ‘problem’. Figures 1 and 2 demonstrate the solutions from two teams.

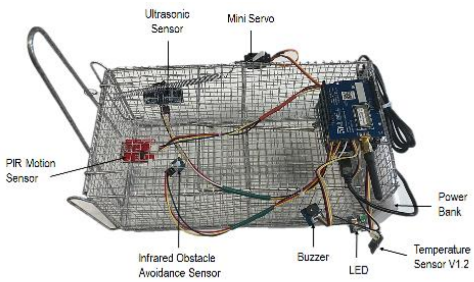

Figure 1. Student Prototype Mouse Trap

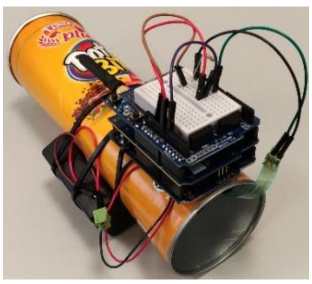

Figure 2. Student Prototype Mouse Sensor

For the same cohort undertaking the module, “IoT in Cities, Industry, Business”, students were engaged in the case study below:

Case Study: Overall Equipment Effectiveness (OEE) of Collaborative Robots

Background: Woo (2017)
Industry: Manufacturing
Issue (In Brief):

- As more companies move towards the adoption of automation and robotics into their operations, IoT technologies are incorporated to track daily operational metrics. One such key metric is the OEE where uptime will directly impact the profitability of the company.
- In this case, the company concerned had purchased two sets of collaborative robots to help with their production assembly. To realize rapid deployment, they wanted to utilize the industry-ready IoT sensor – Bosch XDK110 and the Thingworx Application Platform to capture data that allows for an assessment of OEE.

A widely used industry-based 5-step problem-solving technique based on DMAIC (Define, Measure, Analyse, Improve and Control), as described in Ng (2014), was applied in this case. Solutions utilizing IoT were developed as students moved along the DMAIC methodology as they analysed the different data presented by the sensors in deciding which sensors data are effective in keeping track of the OEE.

A student survey to gather feedback on these modules that used an industry case study approach was conducted. The questions are shown in Table 3 and the outcome of the survey are shown in Figures 3 and 4. On the whole, the survey rated an average of at least 4 for all questions.

Table 3. Module Survey Questions

Q1	The objectives of this module are clearly stated.
Q2	The module has achieved its learning objectives.
Q3	The coverage of the module is adequate.
Q4	The depth of the module is appropriate.
Q5	The lesson materials (lecture notes/hand-outs, worksheet questions, laboratory and practical worksheets) are well designed and organised.
Q6	The lesson materials (lecture notes/hand-outs, worksheet questions, laboratory and practical worksheets) have aided my understanding of the topics covered.
Q7	The contents (such as concepts and skills) presented in this module are useful and relevant to my work.
Q8	The amount of work required in this module is reasonable.
Q9	The assessment method(s) for this module is appropriate and fair.
Q10	The recommended list of readings and resources are useful in increasing my understanding of the contents covered.
Q11	My overall rating of module delivery is…

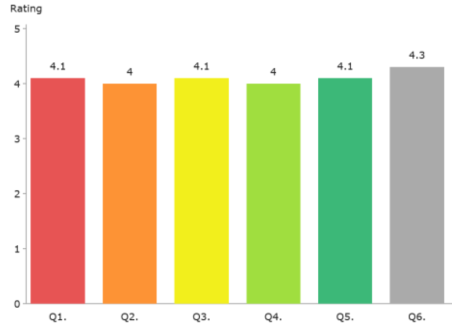

Figure 3. Survey Result for Q1 – Q6

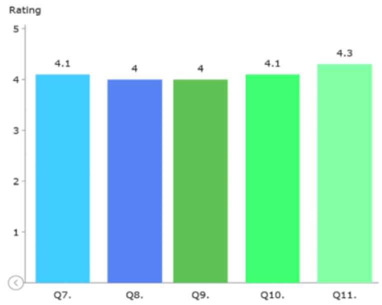

Figure 4. Survey Result for Q7 – Q11

Qualitatively, the overall student feedback was encouraging and on the whole, positive as well. Students claim greater confidence, skills and professional awareness after these modules as they experience the benefit of applying theory and knowledge to practical problems. Even though the problems may be more challenging, they found them energizing.

2. Industry Capstone Projects

In this module, students will demonstrate their competencies in designing, architecting and building a larger scale prototype IoT solution in response to a problem scenario that is provided by an industry partner. In some cases, a problem scenario from the student's workplace can be accepted. It was a clear decision in the design that we wanted students to work on actual industry projects. And student will also work in teams as they would do in the real-world, as much as they will be required to synthesize and apply the IoT knowledge and skills acquired to real-world issues and opportunities. Students will also use this module to further deepen their skills in specific domains of their interest.

A unique feature in this module is the incorporation of Design Thinking as described in Dam (2018). Design Thinking is described as a methodology that is used to solve complex problems and find desirable solutions for clients. The mind-set is solution-focused and action is oriented towards creating a preferred future. Design thinking will draw upon the imagination, intuition, logic and systemic reasoning of the individual and/or team which we wanted to develop in the students as they explore possibilities of what could be and to create desired outcomes that benefit the end user or client. Especially pertinent in the area of smart cities.

To facilitate such an engagement, students will attend a series of design thinking workshops in the module and come up with a proposal for their project based on the industry scenarios. Once the project proposals are submitted, students will be matched with their respective project supervisors and/or industry sponsors for further consultation.

3. Industry Study Tours

The purpose of study tours is to allow students to see theory in practice and enquire of the professionals on site their specific issues/challenges on the ground which can enrich and complement, as well as connect their classroom learning to industry practice. On this, study tours are arranged for internal and external sites. One such study tour was a visit to the Centre of Innovation for Supply Chain Management (COI-SCM) which was jointly set up between RP, SPRING Singapore and the Economic Development Board. This centre specializes in innovation, process re-engineering, and the adoption of technology, including IoT to help companies improve on their supply chain capabilities. In this visit, practitioners shared how IoT solutions used in their supply chain eco system allowed them to gain insights that were previously not possible.

4. Industry Practitioner Delivery

The SDIoT programme actively engages industry practitioners, from the teaching of modules to delivering specialized lectures or seminars including assessment of student projects where possible. These engagements afford students direct exposure to the varied experiences of industry practitioners and often, on topics outside or more advanced than those of the declared learning outcomes. At the point of writing this paper, at least 2 industry seminars had been conducted by industry leaders on such topics. One is briefly described below:

Seminar Title: *Cyberattacks on IoT Systems*.
This seminar addressed the state of security in the IoT space, the pros and cons of current security technologies and standards in IoT, the challenges of Public Key Infrastructure (PKI) in IoT and future security challenges envisaged in IoT.

Industry Associate Scheme

To support professional learning, there are a number of enablers that are key.

- Institutional support in encouraging professional learning is important e.g. putting in place policies and procedures that are "friendly" when engaging external industry partners. Part of this include staff training and development on industry practices to ensure their relevance and currency to the programme.
- Staff being encouraged and trained to develop their teaching practices for professional learning. Staff within the institution need to also work with industry partners to ensure academic rigour.

In RP, one such policy or scheme is called the Industry Associate Scheme (IAS) in which academic staff are encouraged to be associated with the industry in a systematic, coordinated and sustainable way so that the experience that they gather through their association with industry would augment their pedagogic training. Staff are kept abreast with industry trends and are exposed to cutting-edge technologies which increases their ability to create relevant educational problems centred on the institution's unique Problem-based Learning (PBL) pedagogy. In the case of the SDIoT, our practice of Professional Learning.

Mobile Learning and Extended Community Engagement

In keeping with current trends on learning, we have also complemented the programme with the inclusion of a mobile learning platform for professionals called ULeap. ULeap is an initiative of The National Trades Union Congress' (NTUC) e2i (Employment and Employability Institute) in Singapore, in partnership with RP, amongst other institutes of higher learning.

The students, as working professionals, can tap on this convenient learning application to get quick, up-to-date, bite-size information on issues (see Figure 5) and exchange know-how with other experts in the field, including trending discussions, as part of a wider learning community (see Figure 6). This platform and its learning community offers "timely" and a real-world perspective that sets it apart from other learning portals and courses.

Figure 5

Figure 6

Industry Support – Lessons / Insights

Engaging industry is not always easy for reasons of time and effort, for which the benefits to the organization if any, are not immediately or necessarily measurable. We have experienced instances where the benefits of such an engagement from "industry" lay solely on a said individual or two and may be guised as a Corporate Social Responsibility (CSR) initiative. The latter suggest that the position is precarious. For our program, we have expanded and spread our industry engagements across a diverse group of industry partners whose motivations are similarly varied.

Conclusion

The practice of professional learning in SDIoT has seen a number of benefits for both the institution and students. The use of industry case studies and projects, with industry practitioner engagement in the curriculum, brings authenticity and relevance to the curriculum where the students ability to apply the multi-disciplinary knowledge and skills gained to tasks has seen students being more engaged and enthused with their learning. The application of industry practices in addition exposes students to actual workings within industry and they are better equipped to fulfil job functions or seek (new) employment or opportunities. Industry practitioner engagements in the form of study tours and seminars further expose students to the varied experiences of industry practitioners, especially on issues, problems on the ground through 'corridor conversation' that stretch beyond a formal curriculum.

Developing industry engagements is key in a professional learning programme. Initially, it will be time consuming and arduous but as relationships become more established and win-win in structure and nature, the efforts will moderate. On the long term, a virtuous cycle that benefits the institution, its students and industry is on offer.

References

Navin S. (2018). Singapore Tops Global Smart City Performance Ranking in 2017: Study, Retrieved from https://www.businesstimes.com.sg/government-economy/singapore-tops-global-smart-city-performance-ranking-in-2017-study

Teo, B. (2017). GovTech joins the Smart Nation and Digital Government Group, Retrieved from https://www.tech.gov.sg/technews/upclose/2017/03/govtech-joins-the-smart-nation-and-digital-government-group

Weizhen, T. (2016). IT Talent in Short Supply amid Smart Nation Push, Retrieved from http://www.straitstimes.com/singapore/manpower/it-talent-in-short-supply-amid-smart-nation-push?login=true

Knowles, M. (1990). The Adult Learner. A Neglected Species, 4th Edition. Houston: Gulf Publishing.

James, D. B. (2013). Engaging Adult Learners: Philosophy, Principles and Practices

Lawson, R., Fallshaw, E., Papadopoulos, T., Taylor, T. & Zanko, M. (2011). Professional Learning in the Business Curriculum: Engaging Industry, Academics and Students. Asian Social Science, 7 (4), 61-68.

Billett, S, Henderson, A. J. (Eds.) (2011). Developing Learning Professionals: Integrating Experiences in University and Practice Settings, Springer

Henderson, A. (2011). Promoting Professional Learning: Individual and Institutional Practices and Imperatives, Developing Learning Professionals, Springer

Shenna, C. A. (2015). Skills for Success: What IoT Developers Need to Know, Retrieved from http://www.golgi.io/skills-for-success-what-iot-developers-need-to-know/

Duncan. B. (2018). How Universities Can Make Graduates Employable with Connections to Industry, Retrieved from https://theconversation.com/how-universities-can-make-graduates-employable-with-connections-to-industry-91838

Bowe, C.M., Voss, J., and Thomas Aretz, H. (2009). Case Method Teaching: An Effective Approach to Integrate the Basic and Clinical Sciences in the Preclinical Medical Curriculum, Medical Teacher 31(9): 834-841

Herreid, C.F. (2011). Case Study Teaching, New Directions for Teaching and Learning, Volume 2011, Issue 128

Yadav, A., Shaver, G. M. and Meckl, P. (2010) Lessons Learned: Implementing the Case Teaching Method in a Mechanical Engineering Course, Journal of Engineering Education, Volume 99, Issue 1, pp 55–69

Sarah C, Kathrin C., Ann R., Guro H., Anthony A. and Aziz S. (2011). The Case Study Approach, BMC Medical Research Methodology, Retrieved from http://www.biomedcentral.com/1471-2288/11/100

Huiwen, N. (2016). Oh Rats! They're back, Retrieved from http://www.straitstimes.com/singapore/environment/oh-rats-theyre-back?login=true

Fuller, J. R. (2016). The 4 Stages of an IoT Architecture, Retrieved from https://techbeacon.com/4-stages-iot-architecture

Woo, J (2017). Feinmetall to use new tech to lift revenue, capacity, productivity, Retrieved from https://www.straitstimes.com/business/companiesmarkets/local-firm-ups-game-with-6m-digital-manufacturing-facility

Ng, K. C., Chong, K. E. and Goh, G.G.G. (2014). Improving Overall Equipment Effectiveness (OEE) through the Six Sigma Methodology in a Semiconductor Firm: A Case Study, Retrieved from http://ieeexplore.ieee.org/document/7058755/

Dam, R. Teo, S. (2018). 5 Stages in the Design Thinking Process, Retrieved from https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process