

Using Idea 2 Product Labs[®] as a Strategy for Accelerating Technology Transfer

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Abstract

Technology transfer poses particular problems to developing countries whose governments cannot always afford to fund expensive high-tech solutions. This article reports on the Idea 2 Product Labs[®] concept that was developed in South Africa to offer a low-cost open-source alternative. The motivation behind the work was to put innovative new technologies into the hands of more people within a shorter timeframe than would otherwise be possible. The background, planning, objectives, outcomes and impact of the project are reported together with some conclusions on how this model could be adopted across a wider domain.

Keywords: technology transfer, product development, additive manufacturing

1. Introduction

Despite pockets of economic and technological excellence, South Africa (SA) is still categorised as a developing country (ISI 2015). This is certainly the experience of many of its citizens and indeed most of its universities. Despite this fact (or perhaps because of it), the SA government has been actively promoting technology transfer from universities to industry via a number of interventions, most notably the Technology and Human Resources for Industry Programme (THRIP) from the Department of Trade and Industry and the Advanced Manufacturing Technology Strategy from the Department of Science and Technology. These programmes often provide large sums of money and have been used to support the purchase of expensive equipment, including additive manufacturing (AM) systems. However, competition for the funding is high and lead-times can be long, resulting in a lack of spontaneity and flexibility. To overcome these limitations, in 2011 the management of the Technology Transfer and Innovation (TTI) department at the Vaal University of Technology (VUT) was tasked with developing an immediate and effective response to the need for greater awareness and usage of AM, both within the VUT and throughout its surrounding communities.

Using two decades of experience in pioneering the development of Additive Manufacturing (AM) in South Africa (SA) (Campbell et al. 2005; De Beer 2011; Campbell et al. 2011), the lead author developed the Idea 2 Product Lab[®] (I2P[®]) concept to support local innovation, participate in local economic development projects and provide a platform for AM education and research in SA. Using entry-level AM / personal 3D printer platforms, the concept aimed to provide access to AM for school learners, students and individuals wanting to create first samples of innovative product ideas. Whilst following the I2P[®] process for innovation, participants would be exposed to entry level CAD, and would be expected to leave the facility with hands-on CAD skills, and a copy of related software to use at home, office, etc. This should be complimented by hands-on AM skills and the knowledge on where/how AM technologies can be applied to facilitate accelerated product development.

Whilst essentially using entry-level AM platforms, the learning experience envisaged within the I2P[®] lab concept aims to create awareness of high-end AM systems, and will lead users to more advanced applications. Thus, the entire AM industry will benefit from the skills base created.

The paper explains the process followed in creating the I2P[®] lab, states its aim and objectives, and reports local case studies involving school learners, students and individuals. Furthermore, the paper reflects on the development of sustainable research and development (R&D) and technology transfer (TT) facilities in the often remote locations seen in developing countries. Originally aimed at providing a local technology transfer facility, the I2P[®] lab generated much attention on a national and international level. Therefore, this paper also presents the plan for the next phase of the I2P[®] development, namely to roll it out internationally.

2. Idea 2 Product Lab[®] – Change agent for the SA AM Landscape

During 2011, the lead author was part of a team that developed and implemented the I2P[®] concept at the Vaal University of Technology (VUT). The I2P[®], as conceptualised, aimed to bridge the gap left between the existing SA AM industrial landscape, and the then existing SA Government-funded Fab Labs. Further aims were to identify lessons that could be learnt; how to define steps to be included in the AM development road-map; how to use the I2P[®] concept to stimulate educational involvement; and how to attract small and micro-scale companies towards AM usage (De Beer 2012).

2.1 Learning from the history of the SA FabLab initiatives

The SA Government's Department of Science and Technology (DST), under its Advanced Manufacturing Technology Strategy (AMTS), started Fab Labs in different regions of the country to encourage high-level industrial research and development, in parallel with product invention, skills transfer, job creation and solutions to cross the digital divide (Le Roux 2006).

The SA Fab Lab initiative formed part an international educational outreach programme of the Centre for Bits and Atoms (CBA) of the Massachusetts Institute of Technology (MIT) to India, Norway, the US, Ghana, Japan, Spain and Costa Rica. Whilst the Fab Lab programme as implemented in SA stimulated the development of (functional) 3D prototypes, it used off-the-shelf industrial grade fabrication and electronic tools to create parts (e.g. laser cut sheet materials assembled manually) as opposed to AM platforms. In many ways, the Fab Lab programme contributed to 3D-thinking and a better understanding of layered manufacturing – albeit through conventional manufacturing approaches.

3. Idea 2 Product Lab[®] Planning

3.1 Positioning of the I2P[®] to impact on national imperatives/strategies

South Africa in general, but more specifically the poverty-stricken region of Southern Gauteng that surrounds the VUT, is challenged with low levels of skills development, underpinned by insufficient job opportunities. As part of an integrated national solution, the VUT proposed the development of the I2P[®] lab where, as a strategic intervention, individuals from the region could be provided with the following:

- appropriate skills development;

- infrastructure for entrepreneurs to develop new products that could be tested and modified in the market place according to customer needs;
- increased adoption and transfer of technology and research and development into new tools for entrepreneurs.

The I2P® lab concept contributes towards this by moving individuals along a continuum that starts with improved education and ends with entrepreneurial activity. The I2P® lab equipment on its own can be used as an AM educational platform. The addition of design skills teaching and concept generation techniques will then encourage the students to explore innovative solutions to new or existing problems. Finally, the further additional of business acumen training and incubation facilities will allow some of the students to branch out as entrepreneurs, pursuing their design ideas towards a marketable product. Direct entry into any of the three levels can also be made by individuals from the local community.

3.2 Broad aims and objectives

The project (through its dedicated and virtually linked facilities) aimed to provide appropriate infrastructure to produce small batches of niche products. As part of the planned project outcomes, it is envisaged that the I2P® would contribute towards

- creating jobs and helping the region's very poor communities improve their economic situation;
- increasing the focus on high value-added manufacturing initiatives in the Southern Gauteng region;
- supporting people doing business in the grey economy to move to the mainstream economy in the Southern Gauteng region;
- developing human resources and building multi-, inter-, and trans-disciplinary or cross-cutting research skills;
- facilitating the development of new industries and product development initiatives by encouraging joint research and community interaction;
- developing and supporting competitive small enterprises;
- providing an enabling infrastructure for innovators.

The I2P® lab was made available to innovators, students, school learners, small and medium (and micro) sized enterprises, general industry and other entrepreneurs. In short, any person from the local communities in need of support for the development of a specific idea, could access the I2P®.

3.3 Training objectives

The I2P® concept follows a holistic product development approach, focussing on manufacturing of the complete product to include design, fabrication, testing, debugging, monitoring and analysis, and documentation of the process. As such, it facilitates the delivery of market-ready products. It also facilitates peer-to-peer learning, which contributes to personal development of the participating students or community members. This is also a significant attribute towards the project's sustainability.

The lab and its infrastructure were not just about material manipulation, but also allowing for rapid development of innovative concepts. In addition, rapid learning is possible and new innovative products could be prototyped in hours, literally. The I2P® lab therefore also served as a training infrastructure that would teach students, innovators, entrepreneurs and business people how to use AM and how to develop local innovation models, as sustainable innovation often comes from within. As such, a home-grown model of the MIT's *"how to make (almost) anything"* (MIT 2015) was developed within the I2P®. In addition, the VUT's staff and students pursue ongoing research to introduce new tools and facilities to the Lab that can assist users to *"make almost anything"*. It has also served as a research platform to stimulate innovation and development of new AM technologies or platforms.

The VUT has also been using the I2P® project to engage with other universities (both nationally and internationally) in basic research to support the I2P® lab, and then to introduce new innovations to benefit the local community or solve local industry problems. Furthermore, it supports the overarching goal of instilling innovation as part of the core curriculum in all learning programmes.

4. Project Outcomes

Various positive outcomes can be reported since the inception of the VUT's Idea 2 Product Lab® project, and are discussed below:

4.1 Using the Idea 2 Product Lab® as an extension of undergraduate laboratories

The Technology Transfer and Innovation Department of the VUT was approached to make personal 3D printing (P3DP) equipment available for undergraduate teaching of advanced manufacturing processes in the Industrial Engineering course. Students were invited to use the Idea 2 Product Lab® to execute design projects, and in such a way to understand the impact and role of design and AM in advanced manufacturing process development. A further point of interest is that students with no prior exposure to AM took on significant challenges. More importantly, these students devoted a Saturday morning to attend the Idea 2 Product Lab®, which indicated the importance they attributed to using the facility. Furthermore, the students were exposed to the potential of the Lab, through seeing designed products, action figures and other creatures or devices being built on the P3DP machines. Since inception, approximately 7 500 students have attended the Idea 2 Product Lab®, resulting in more than 20 000 parts being designed and produced. This success also led to using the Lab in the Industrial Engineering coursework, as explained below.

Production Engineering IV is a first semester subject for the Industrial Engineering and Operation Management undergraduate students and was taken by approximately 85 students in the 2014 class. One of the objectives was for students to be exposed to product design using Autodesk 123D Beta or any similar software (depending on their level of CAD understanding), followed by Additive Manufacturing, using the Idea 2 Product Lab® facilities. The brief was for the design to be an improvement on commercially available products or to solve industry-related problems (bonus marks were awarded for product and design complexity). The students also had to submit a written report on their designs, the AM process they used, and how it supported them in the product development process. Figure 1 shows a collage of products developed as part of the semester's projects.

Further uptake in terms of undergraduate or postgraduate student work has been seen in Metallurgical Engineering, Mechanical Engineering, Electrical Engineering, Computer Systems Engineering, Industrial Engineering, Information Technology, and Fashion and Design's adoption of the use of AM in the curriculum. Further development in process that will rely on the I2P® lab for execution is in Biotechnology, with a view to future development of Tissue Engineering.



Fig 1: Collage of products developed as part of the Industrial Engineering projects

4.2 Rolling out of the Idea 2 Product Lab® concept

In South Africa, the VUT started three more Idea 2 Product Lab® installations in its different campuses, Science Park and Technology Stations. One of these was started in Upington in the Northern Cape, which also highlights the rural impact that it can make. One facility has been developed at the South African Bureau of Standards (SABS) Design Institute (Figure 2), and one is earmarked for Cape Town, as an extension of the Design Institute, and another at Stellenbosch University. Three more are being implemented at the North West University's different campuses, and two industrial-oriented labs are in planning as part of a public innovation laboratory.



Fig 2: SABS Idea 2 Product Lab®

Internationally, Colorado State University, the National University of Singapore, Auckland University of Technology and Loughborough University, have all started hybrid versions of the successful concept. Some have used the Idea 2 Product Lab® name, whilst others, e.g. Loughborough University, have used their own terminology, but in principle are still keeping to the same idea.

4.3 Case Studies

4.3.1 Industrial Case Study: Batch Production Test

With the visual quality of parts produced on P3DPs coming closer to that of high end AM machines the Design Department at the VUT Technology Station in collaboration with the Idea 2 Product Lab® management and staff, designed a part for production using a low cost AM printer. During the design phase, it was realised that design samples printed using acrylonitrile-butadiene-styrene (ABS), performed very well as functional parts. A decision was made that the parts would be produced using P3DPs (UP Mini machine). This opened up the design options to include customisation, together with the option of flexible production. Two important aspects for designers to keep in mind when designing for entry level 3D printers is wall thickness and sloped areas. The printing direction will also influence the strength of the final part (La Grange et al 2014). As shown in Figure 3, layer lines are clearly visible on the sloped areas. It was determined that the printing of a straight slope gave a much better surface finish compared to a rounded slope, as shown in Figure 4.



Fig 3: Partially printed bottom part

Fig 4: Bottom part

It was found that post processing the parts with an acetone vaporizing treatment improved the surface to give a smooth finish as can be seen in Figure 5. The case study proved that with appropriate post processing, P3DPs can be used to produce visually good quality parts when volumes do not justify injection moulding. Also, by designing for this process, supports can be built in the model to ensure acceptable performance of parts. In addition, design for AM is not bound by the same laws as design for injection moulding, where typically, a uniform wall thickness is needed to circumvent warping. Furthermore, the use of gussets, ribs or other forms of internal stiffeners do not cause heat sinks on the adjacent surface (normally seen on the outside of the part) as with injection moulding. Due to the proven P3DP manufacturing method, customising of parts became a viable option.



Fig 5: Bottom part after post processing

Another advantage was that several primary colours were available. In this case study the colours blue and white were used, as it suited the particular application. The low acquisition cost of the latest P3DPs makes it possible to set up a low-cost manufacturing unit comprising several printers. Bulk acquisition of P3DPs will result in higher volumes of parts that can be produced in the same time frame. The P3DPs used (UP Mini machines), also proved to have a very low maintenance requirement with a relative low cost implication when failures occur. Also when a printer is out of production due to cleaning or maintenance, total production will not stop as multiple machines are in use.

4.3.2 Entrepreneur Case Study: development of drone parts to lead to a new company

Figure 6 shows a collage of images that represent the complete development of a radio-controlled gimbal and mount, crucial for the stabilisation of, for example, a camera mounted on a drone. Part of the achievement is that the P3DP and Idea 2 Product Lab® concept was introduced to a hobbyist/entrepreneur who saw the opportunity to develop drones for specific remote inspection applications. After consulting with the lead author regarding P3DP usage versus conventional machining technologies, the client invested in an UP Mini, downloaded Autocad 123D and started designing complex integrated mechatronic devices, as shown in the collage. This verified findings from previous research by the authors that P3DP machines are capable of creating highly complex parts (Pei et al. 2011; Lotz et al. 2013). He went on to design and manufacture various connectors to fit standard extruded aluminium sections, manufacturing jigs, fixtures, gimbal plates for robotics,

etc. Experience gained in this particular project and processes used, supported him to develop a new niche-market company.

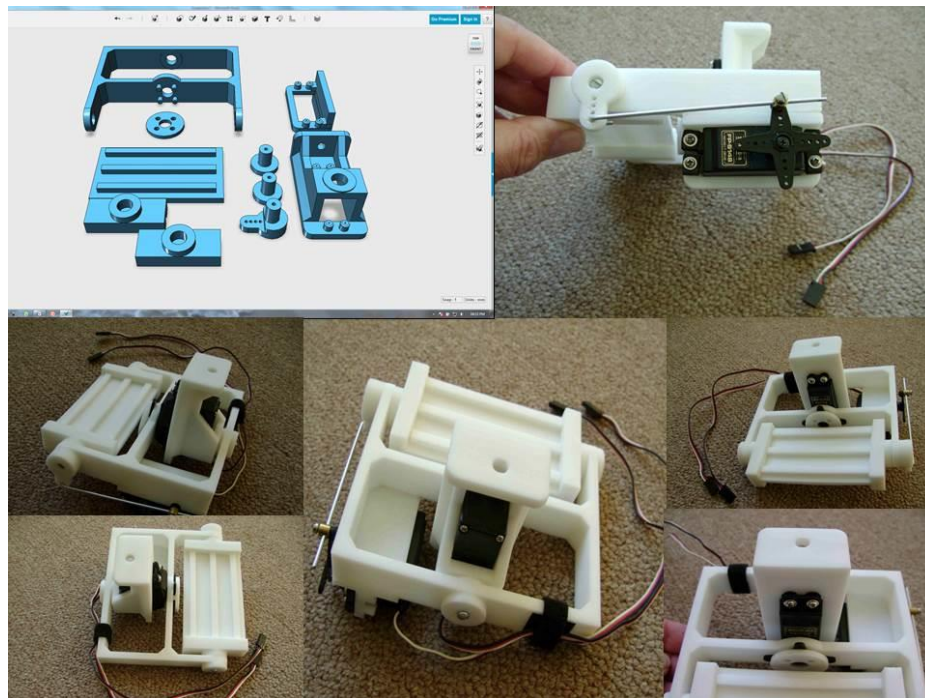


Fig 6 – Gimbal Development for a radio-controlled drone

4.3.3 Research Case Study: Medical Product Development

Whilst reviewing a completed project that was undertaken for a medical practitioner, it was found that an anaesthetic mouth piece was due for redesign. Having been intimately involved in the initial product, the team members decided to avoid the previous pitfalls associated with a conventional new product development (NPD) process, namely to do design modelling, grow prototypes, and make both soft and hard moulds to arrive to a “testable” product. Instead, they decided to directly employ P3DPs to make the prototypes for testing in medical grade materials. This required numerous experimental studies to optimise the parameters used during the design build process. Eventually, it was possible to take three steps out of the NPD process, with approximately US\$8,000 overall savings. The project produced excellent prototype results, as can be seen in Figure 7. Experience gained in this particular project and with the processes used, led to a new spin-off company being started by three of the staff members involved. In addition to providing design, reverse engineering and AM consultancy services, the first product produced is a new generation prosthesis, using direct digital manufacturing.



Fig 7: Anaesthetic mouth piece directly manufactured using a P3DP

5. Strategic impact on the host institution

For any university, albeit through strategic partnership opportunities, the development of an AM research centre is an expensive undertaking. From a national system of innovation and funding perspective, sustainability, together with proven capacity is an important consideration. As such, it is almost impossible to fund a significant development in a short timescale, and obtaining piece-by-piece funding has proven to take significant time.

Therefore, using the Idea 2 Product Lab[®] as an AM teaching and development instrument proved a worthwhile route for the VUT. This is not very different from past international successes and benchmarks as reported by Wong et al. (2014), where the Nanyang Polytechnic has applied its Teaching Factory Concept to train students and industry personnel on relevant AM technologies with real industry applications. One of the significant benefits of the Idea 2 Product Lab[®] concept was the relative high number of machines available, and the “freedom to operate” policy, enabled through the low cost of the entry level machines in use. Although the set-up and running costs are low in comparison to high-end or industrial grade AM equipment, the philosophy or paradigm taught in terms of design and direct digital manufacturing, remains the same.

For VUT staff, students and industry partners, it created an opportunity to specialise in design, as well as to investigate real industrial applications. This “learning experience” was successfully applied to develop specialised high-end application units, backed by excellent design capabilities, as well as a full understanding of the relevant AM processes and peripheral support infrastructure. Amongst others, it was reported that students who learned CAD in the Idea 2 Product Lab[®] environment, within a few weeks performed far better in CAD operations / applications than students who only had the formal CAD semester training. In addition, all students who were I2P “graduates” and employed as interns in the university’s Advanced Manufacturing Precinct, were productive right from the start. An interesting observation was that approximately 60% of these students were employed in industry before completing the internship at the university, which also proved that the I2P[®] lab was making a national contribution to skilling students for strategic industry needs.

Using the I2P[®] lab as an open facility, researchers in various fields (e.g. renewable energy, with a specific focus on fuel cell control mechanisms), started using the lab to manufacture critical research components (essentially at near zero cost, and on a just-in-time basis – normally overnight), to help

foster a multi-, inter- and trans-disciplinary research culture. Further examples are design studies that crossed over into robotic-driven devices, with a special emphasis on texturing and surface finish. The external attention that the I2P® lab created, also attracted natural innovators, and realised a new technology transfer driven research paradigm. Prime examples are the increased understanding of AM processes, which not only led to improved outputs, but also led to the development of next generation machines and operating software. For example, research students have already produced their own STL slicing and plotting software. In addition, a versatile inkjet powder printer is under development – all under the contributing students’ own initiatives. A current group of students will all be developing their own entry level 3D printer.

6. National strategic impact

The introduction of the I2P® lab at the VUT has paved the way for a number of larger technology transfer initiatives to commence. When SA Government offices recognised the VUT’s commitment to technology transfer and the successful outcomes from the lab, they realised that specific industries could benefit from an expanded version of the concept. These initiatives make use of high-end AM equipment including polymer powder bed fusion from EOS, binder jetting from Voxeljet and material extrusion from Stratasys. The use of this high-end professional equipment reveals that not all technology transfer projects can be delivered using low-cost solutions. In the case of AM, the change-over to high-end equipment will typically come when greater levels of reliability, material properties consistency, and component complexity are required. In a nutshell, it is when AM is going to be used as a *bona fide* production process alongside established technologies such as injection moulding, casting and CNC milling.

6.1 South African Foot and Leatherwear Innovation Centre

The design and AM base at the VUT brought about by the availability and support of the I2P® Lab supported a case to involve AM in reinvigorating the SA Footwear industry. This led to a high-end advanced manufacturing centre being funded by the SA government, with special emphasis on design and additive manufacturing. The I2P® labs were also approved as regional innovation centres for the shoe industry. AM is being used to make sample lasts, shoe sole moulds, wedges or complete designs, with cases being documented where complete development, including off-tool samples, needed less than a week – a unique situation world-wide. These results correspond very well with the findings of Manoharan et al. (2013), in terms of AM accelerating the shoe design process.

6.2 Casting programme

In the same manner as above, the National Foundry Institute supported the VUT in attracting further government funding to develop a foundry innovation centre, with related high-end equipment. The I2P® lab was also used to support a “New Generation Foundrymen” course to introduce CAD, CAM and AM technologies to trainee foundrymen (and women).

6.3 Aerospace and tooling

As a further direct consequence of the I2P® lab, discussions were held with Aerosud, a leading SA aerospace company, towards making further investments to acquire high-end polymer AM

equipment for the development of jigs, fixtures, tooling and aircraft components. To date, more than 500 flying parts have been made – some of which are structural parts.

7. Conclusions

With the advent of the “Makers” movement, it was anticipated that internationally, the next phase of the digital revolution would go beyond the current wave of personal computation to personal fabrication. Ideas were generated on how South Africa could move in the same direction to facilitate technology transfer support for learners and local communities in this domain. The result was the VUT’s Idea 2 Product Lab® concept that now provides a new home-grown technology transfer model that is empowering people through giving them access to personal fabrication in the form of entry level AM platforms. The Idea 2 Product Lab® has proved to be a catalyst to create an innovation culture within the host university and amongst innovators in the surrounding region. The existing ideas that innovation can be borne through blending indigenous knowledge with technological inputs from the developed world, are gaining more substance within the VUT’s Idea 2 Product Lab® initiative.

On a wider level, this work shows that technology transfer within a specific domain does not always need to depend upon high-tech expensive solutions, particularly within developing countries. The domain studied here was additive manufacturing coupled with design software. The low-cost Idea 2 Product Lab® concept was made possible by the rapid development of easy-to-use, often open-source technologies. However, this is a story that is being repeated in many domains, where the ubiquitous nature of computing and the sharing of ideas over the Internet is driving technology innovation at an unprecedented rate. Technology transfer organisations, particularly those in developing countries, should embrace this low-cost, open-source strategy as a means of giving more people accelerated access to new technologies.

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