Collaborative Project Based Learning in Novel 3D Printer Design

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Abstract: This paper is a report on a comprehensive Problem-based learning (PBL) approach, applied in the frame of a final year project, in the study of Advanced Manufacturing and Mechatronics at RMIT University, and in collaboration with the industry. The main project objective, from the engineering point of view, was the development of a new product, 3D Printer for metal printing. From the engineering education point of view, we had problem definition, project organization and management, theory and practice integration, participants' directions, multidisciplinary team approach, collaboration and feedback at various levels and institutions. Additive manufacturing, or 3D printing, is emerging as a technology that is already changing engineering and manufacturing. Currently extensively used in prototyping, 3D printing practice is becoming more interesting with a wider choice of materials available. Company SPEE3D developed a process known as SPEE3D print, which enables metal components printing at higher speeds compared to conventional powder bed metal printers. RMIT University and SPEE3D have already established collaboration across a number of projects. Multidisciplinary projects are in the areas of robotics, mechatronics, industrial design, computational fluid dynamics and schlieren photography. The project presented here, was funded by Future Designers Grant from the Department of State Development, Business and Innovation, Victorian Government, Australia. Final product, new 3D printer, designed by students, has received a Bosch Venture Forum Award in Germany, in June 2015. This was a great international recognition of PBL student centred approach, applied in our engineering education practice, as well as University and industry collaboration, supported by Government funding.

Keywords: PBL, collaboration, 3D printing, additive manufacturing, student centred learning

1. Introduction

RMIT University is one of largest Australian Universities with international recognition for excellence in professional and vocational education, research and collaboration with industry and community. As a dual sector University, RMIT includes project based learning as a contributing factor to all engineering graduates' work readiness, as requested by Engineers Australia (M Jollands, Jolly, & Molyneaux, 2012). It supports this through a large variety of its programs, resources and collaboration with the industry. University has one of Australia's leading 3D printing facilities, the Advance Manufacturing Precinct (AMP). It is used for the teaching and research across multidisciplinary areas, schools, industry, medical science, art and design, architecture and others.

University is working closely with a huge number of collaboration companies, starting with large companies like Boeing, Siemens, ABB, Telstra and many others, up to the small, start-up industry players. Large number of successful collaboration were already reported (P.T.J., Simic, & Dawson P, 2008; Simic & P.T.J., 2008). This practice continuous and improves each year. Finally there is

Government involvement with financial support to both the University and industry, when they expressed interest to work collaboratively (Simic, 2004, 2006; Simic et al., 2006).

SPEE3D is a new company established to change the face of manufacturing by developing a novel high speed, metal printing 3D printer. Start-up companies such as SPEE3D can iterate quickly, developing new ideas, testing and implementing results. Expectations are based on licencing and patenting already approved. These companies, however, generally have limited resources and funding. Working together with the University, the company helps in developing engineering students' graduate attributes, as defined by Engineers Australia, understanding of manufacturing and sustainability using real life projects (Margaret Jollands & Parthasarathy, 2013).

The skills and resources of RMIT and SPEE3D are complementary and provide an excellent opportunity for collaboration in developing new technology. The project "*A multi-disciplinary design approach to identifying growth opportunities in 3D printing*" was supported with a Future Designers grant, by the Victorian Government, and has continued on, following the completion of the grant. The project was multidisciplinary with the involvement of academics and students from different areas, such as, mechatronics, industrial design, business, computational fluid dynamics, robotics, mechanical engineering and computer science.

2. Project Management

Following reach collaboration, already realised in large number of successful engineering educational projects, a joint team put a Victorian Government grant application and the end of 2014 academic year. The main project objectives were to solve the problems that prevent metal 3D printing from becoming a true advanced manufacturing technology. Expectations were that SPEE3D's new technology will allow metal 3D printing at the faster speeds than the speeds achievable using existing 3D printing techniques.

The project had a number of distinct phases as shown in Figure 1. Successful grant opened the door for more meaningful cooperation, project based learning for students and business development for industry partner. While collaboration team was responsible for the whole project, including all tasks from 1 to 16, students' PBL projects were conducted in the framework of tasks 6 to 14.

This complex project was initially broken down into a number of subprojects to deal with industrial design, mechanical, mechatronic design and business planning. Of particular importance for both the industry partner and University was the grant constraint in time. Whole development with the design, test and build phase had to be completed in only 12 weeks. Successful completion of these elements allowed demonstration of the technology and follow up projects in the areas of robotics and printer head design/testing. The first prototype of the printer was designed using Computer Numerical Control (CNC) technology. Second generation was later designed using robotics. It was another multidisciplinary, multi-schools and industry collaboration project.

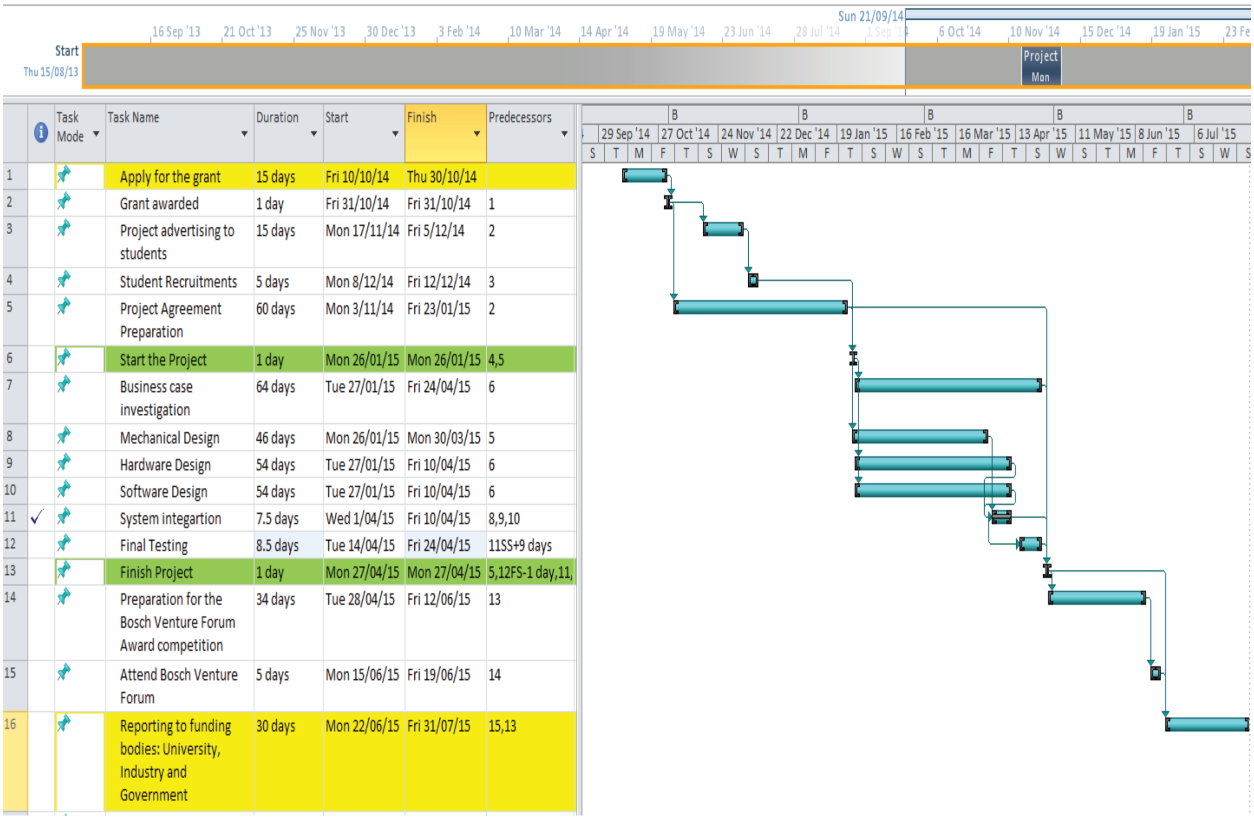

Figure 1 Novel 3D printer design project Gantt Chart

3. PBL Projects for Students

Using a Future Designers Grant awarded by the Department of State Development, Business and Innovation, Victoria, RMIT University and SPEE3D developed a breakthrough in 3D printing technology. An academic supervisor from the School of Aerospace, Mechanical & Manufacturing Engineering (SAMME) led the RMIT team and whole collaboration team. Students from different schools were working closely with the industrial partner's team under the supervision conducted by company's Managing Director and academic supervisor.

First of all, Mechatronic and Industrial Design students worked with academic supervisors alongside with SPEE3D personnel in developing a proof of concept printer. Business students, with their academic and industry supervisors were working on a commercialisation plan expressed in that task 7 which was "Business Case Investigation".

- Task 7 was seen as PBL project for Business students and for the students studying Master in manufacturing Management.
- Task 8 together with the tasks 11, 12 and 13 were core of the PBL projects for the students studying Mechanical Engineering and Industrial Design.
- Tasks 9-13 were core for PBL project conducted by Mechatronics students.

This approach to multiple, concurrently running students' PBL projects enabled start-up company SPEE3D to develop and test key components of the new technology. The company mapped out a path to take the business opportunity to the next stage.

The approach of breaking the larger project into short, concurrently running, sub-projects was vital to the success of the whole project. Students' PBL projects had time allocation of exactly 12 weeks, in total, as per Agreement between Government, University and Industry. Please see tasks from 6 to 13. With such a tight timeline, defined by the Government, high risk design elements were identified up front and strategies put into place to solve these issues. Students were selected that had background in design, and manufacture of industrial components, which enabled a quick ramp up time. The following chapters present the key project, i.e. sub-projects design elements.

4. Mechanical Design

Nowadays, nearly all engineering project are multidisciplinary. RMIT's Industrial Design School was approached for the design of external and functional elements of the printer. Key specifications for mechanical / industrial design included following requirements:

- Aesthetic and overall sound design – including material and part loading and unloading, sound proofing, ancillary component location, user interface and of course Occupational Health and Safety (OHS).
- Ease of manufacture – design and build to be complete within defined timeframe
- Low cost – project budget required a low cost prototype design.

The basic body building blocks were selected first. Mood boards were presented followed by overall concept sketches. Examples of these are shown in Figure .

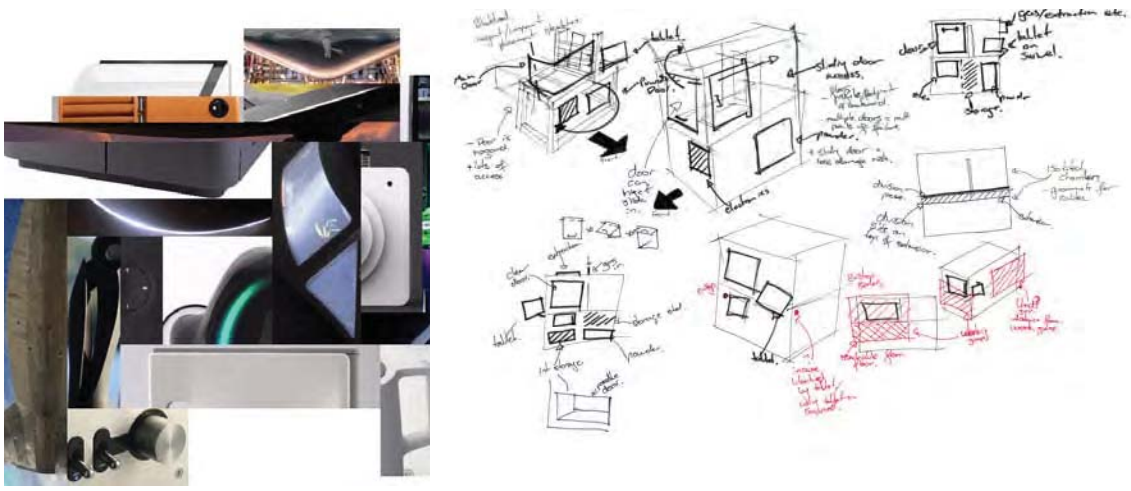

Figure 2 - Printer Industrial Design – Mood board and Concept Sketches done by students

The design was iterated from the initial concept sketches throughout the project length. Final renders, i.e. actual machine body is shown below in Figure 3

Figure 3 – Industrial design final outcome – 3D Printer body

Finally, all industrial design elements were created by a final year student from the Design School. Following the completion of the grant, SPEE3D Company has employed the student, now designer, for a 2nd generation printer design. This is the way how student's PBL final year project is converted to employment.

Mechatronic Design through Hardware and Software PBL

The most important subproject, i.e. students' PBL, for the success of the new printer development was the mechatronics design. Mechatronics includes mechanical, electrical, electronics and computer science design that can bring life to the engineering constructions. A final year mechatronics student was engaged to take care and design the following elements and sub-systems:

- selection of motors as actuation devices
- sensors selection for data acquisition (DAQ)
- control design and electronics
- selection of software and software design environment
- design of mechanical components including bed, frame and associated hardware
- programming of software
- sub-systems assembly and whole system integration
- final testing of the hardware and the whole system.

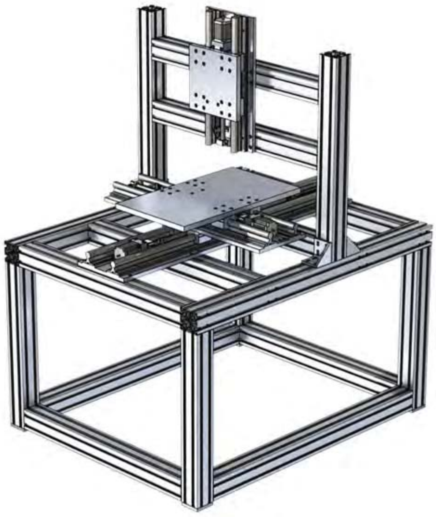

Figure 4 - Mechanical Design – Internal frame of the printer with CNC setup

Because of the relatively short project time emphasis were placed upon short lead time and readily available components.

Print Head Design and Testing

The heart of any 3D printer is its nozzle. It is a micro jet engine that is shooting metal particles in our case. Outside the Future Designers grant supported activities, equally important was the development of the printer nozzle. SPEE3D team was working with a Masters student from School of Engineering to model the nozzle using computational fluid dynamics. Results from this investigation have showed trends expected from the design. Figure 5 shows particle stream simulation results obtained by the application of computational fluid dynamic. The main objective was to achieve minimum dissipation of the material outside of the small targeted area.

A nozzle sub-system was subsequently built and successfully tested in the proof of concept printer. To validate the design and visualise the gas flow, Schlieren Photography was used. This involves the use of a light source, two mirrors and a high speed camera as shown in Figure 6.

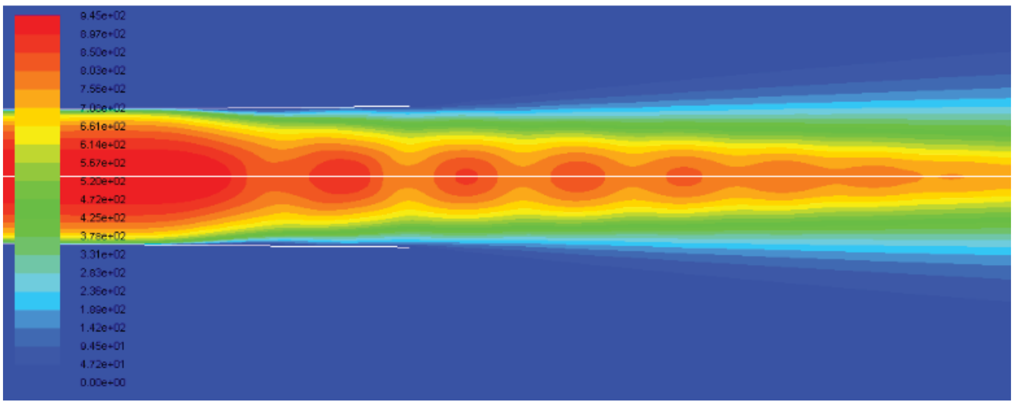

Figure 5 – Results from computational fluid dynamic presentation of particle stream

University has provided the equipment and academic/student knowledge to assist in capturing images, as shown in Figure 6b.

a) Lab setup b) Gas flow image

Figure 6 – Schlieren photography setup and gas flow image captured

5. World Recognition of RMIT University Work Integrated Learning

Every year Robert Bosch Venture Capital (RBVC) holds an event where a hand-selected group of applicant start-up companies are invited to the world headquarters of Robert Bosch in Stuttgart. They have to present their new technology ideas to senior management. RBVC is the corporate venture of Robert Bosch GmbH, one of the largest private companies in the world with more than 360,000 employees. Our new technology was presented and recognised in June 2015. Industry partner, SPEE3D, was presented with the Bosch Venture Award by RBVC, demonstrating the success of the joint University / Industry project, supported by a Victorian government grant. Core activities and whole product development was mainly conducted by our University students. It is great world recognition of Australian Engineering Education.

6. Conclusion

This project is an excellent example of collaboration between a start-up company and an established University under the support from the Government. Keys to success were short, sharp, focused sub-projects and understanding the strengths of the two parties involved. The University has expertise and facilities outside the scope of any start-up businesses, however, collaboration enabled excellent results for the company, students, University and the community. A small grant has initiated long term collaboration, which still continues, in the development of new technologies and practical, real life Engineering Education.

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