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Teaching towards Design-Based Learning in Manufacturing Technology Course: Sino–Australia Joint Undergraduate Program

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Received: 19 March 2020; Accepted: 22 April 2020; Published: 25 April 2020

Abstract: The internationalized higher education in Engineering has made the sustainable future of Chinese regional universities prosper in the recent decade. The teaching practices of engineering courses pose many challenges in Sino–foreign joint undergraduate programs. The design-based learning (DBL) approach addresses students learning challenges in the joint undergraduate program facilitated by the Wuhan University of Science and Technology (WUST) in central China along with Deakin University (DU), Australia. Following the seven general principles of DBL, a project of process planning was performed for teaching and learning in the Manufacturing Technology course. An implicit meta-cognitive competence was developed through performing the engineering project tutoring, diverse learning tasks and normative assessment criteria. The DBL pedagogy succeeds in bridging the diverse knowledge systems in the specialized courses of Manufacturing Technology between Chinese and Australian programs in Mechanical Engineering. Many achievements and awards won by the students demonstrate a satisfactory result in the case study on the teaching practice towards DBL. The pedagogy towards DBL truly improves the teaching quality of the courses in joint programs and further strengthens the internationalized engineering education for the sustainable development of regional universities in China.

Keywords: internationalized education; joint program; DBL; implicit meta-cognition; manufacturing technology; mechanical engineering; sustainable development

1. Background of the Sino–Australia Joint Undergraduate Program in Mechanical Engineering

1.1. Worldwide Development of International Joint Engineering Education

The wave of globalization promotes the internationalization of higher education, especially in the expertise field of Engineering. Many well-known universities, such as Cambridge and Harvard, began to exchange their undergraduates and graduate students in Engineering for closer scientific research cooperation as early as the last century. In Europe, 12 EU countries started a European unified educational program named ERASMUS (European Action for the Social Mobility of University Students) in 1987 [1]. When entering the new century, Oxford and Princeton started several joint doctoral programs in the global engineering and economic fields in 2001. In Asia, the Japanese Kochi University prioritized scientific research and professional teaching cooperation in the fields of agronomy, soil science, ecology and engineering with developing countries in the Asia-Pacific region [2].

Under the national Belt and Road strategy, China also desired to internationalize its higher education through running joint programs in advanced subjects with well-known western universities [3]. Many top universities, such as Tsinghua University, Peking University, Wuhan University and Huazhong University of Science and Technology (HUST) succeeded in joint engineering educational programs on various scales and levels. For example, Huazhong University of Science and Technology and Xi'an Jiaotong University have run joint undergraduate programs in Engineering with the University of Michigan in the United States of America for decades. The major courses in these programs included Mechanical Design and Manufacturing, Thermal Engineering, Automotive Structure and Powertrain, Traffic Engineering, etc. Major students would go to the University of Michigan to continue their senior semesters and subsequently pursue the master's degree if they desire. Likewise, the analogous undergraduate joint programs were held by thousands of regional universities located in China and other countries worldwide, including the authors' schools, the Wuhan University of Science and Technology (WUST) in China and Deakin University (DU) in Australia. Considering the students' adaptivity to the teaching mode at various universities in various countries, some internationalized educational approaches should be proposed and improved for better effects on the teaching and learning in the joint programs.

The world is facing several challenges that include natural disasters, environmental issues and socio-economic and political problems. We believe the current student forces that will be engineers, technical experts, educators and scientist in the future are capable of facing the global measured problems articulated by the United Nations' 17 Sustainable Development Goals (SDGs). To acquire the qualities of addressing the difficult problems and maintain the sustainability of human life and education, we need to adapt new pedagogical approaches to the education environment, i.e., the classroom teaching space, which supports the students' learning process in a team and makes them self-motivated to be sustainable engineers of the future workforce. It is a necessity of a young graduate to be sustainable in a five to ten years of a career. This led us to ask what the learning experience might look like if we explored different learning and teaching ways to educate for complexity and sustainability.

1.2. Brief Introduction to the Sino–Australia Joint Program in Mechanical Engineering Expertise Goals and Course System

With the approval of the Ministry of Education of China, WUST and Deakin University have jointly started an undergraduate program in Mechanical Engineering in 2013. The program grant number is MOE42AU2A20131394N. The program level is categorified into engineering education with a bachelor's degree. It is allowed to admit undergraduate students under the national general higher education admission program.

In the joint program, WUST and Deakin University jointly develop a talent-training plan and select outstanding teachers to join this program. Deakin University undertakes on third of the core professional courses, and the main courses are taught either as bilingual courses or full-time in English. The duration of the joint program is four years. Students can complete all of their studies and pass all tests at WUST, with required credits. That means that they can obtain a diploma certificate and a bachelor's degree from WUST, but students have another choice. If their English level reaches the entrance standards of Deakin University, and meanwhile their academic performance meets the requirements of both universities after 2.5 years of study in this program, students can choose to continue their studies in the undergraduate program at Deakin University at their own expense. Deakin University acknowledges 16 credits earned in China. After completing the remaining 16 credits in an undergraduate program in Mechanical Engineering at Deakin University, usually taking two academic years, students can obtain a bachelor's degree in Mechanical Engineering from Deakin University. They can also obtain a bachelor's degree and a diploma certificate from WUST. Furthermore, Deakin University has a variety of scholarships, such as DUISP (Deakin University International Scholarship Program), DUIRS (Deakin University International Research Scholarship), and IPRS (International Postgraduate Research Scholarship) available for the students in the joint program. Students who have earned eight credits via completing full-time courses, usually in one academic year, can apply for the DUISP scholarship with an amount of about AUD 5000 per academic year.

Students in this program gain knowledge in the basic theories of machine designs and manufacturing, learn electronic technology techniques and gain fundamental knowledge of computer technology and information processing technology; they receive basic training for engineering design, calculation, drawing and equipment fault diagnosis; and acquire basic competencies needed in designing and manufacturing mechanical products, controlling the machinery subsystem, and organizing the production process. Most importantly, the students graduating from this joint program obtain the capabilities of cross-cultural communication and a sense of competition as well as cooperation, with an international vision.

1.3. Challenges in the International Joint Undergraduate Program

Comparing with the top universities administrated by the Ministry of Education, most regional universities in China confront more challenges while running the Sino–foreign joint undergraduate programs, as detailed in the following:

1. Due to the lack of substantial cooperation with internationally renowned universities, regional universities in China generally lack high-quality education resources from overseas universities; additionally, teachers are lacking to meet the requirements of international engineering education [4]. Moreover, the teaching methods usually used in the existing engineering education make it difficult to meet the requirements of joint programs for training internationalized engineering talents. The lack of internationalized educational methodology severely restricts the development of internationalized education in regional universities.
2. Students in regional universities possess insufficient capabilities in cross-cultural communication, dealing with international affairs and familiarly using international standards. The traditional engineering talent training system pays insufficient attention to international rules, international practices and cross-cultural communication, and lacks the adequate teaching ability; therefore it is difficult to meet the requirements for training innovative engineering talents under new situations of internationalization, that is, for the implementation of the national developing strategy of Belt and Road.
3. The core curricula established in the Sino–foreign joint programs consist of the advantage and featured curricula chosen from Chinese and foreign curricula systems. However, completely integrating the domestic and foreign engineering knowledge together to form an adequate knowledge system for engineering talents is another challenge lying in the way of educational internationalization for regional universities. Due to the differences in talent training goals between Chinese and foreign courses and the contents of professional courses, the knowledge systems from domestic and foreign programs are difficult to form into an organic unity, which is harmful to the shaping of students' professional knowledge structure and their global vision.

1.4. Teaching Approach to Addressing the Challenges in International Joint Programs

For addressing the challenges mentioned above, WUST and DU faculty in the Sino–Australia joint program continuously explored the internationalized mode for training engineering talents that better suit the characteristics and conditions of regional universities. They attempted different approaches, which teach students not only knowledge in Mechanical Engineering but also practical skills and engineering competences. In the new approaches, students should no longer be preoccupied with specific technical knowledge instead of working on the development of internationalized engineering competences. Through working in teams to tackle an open-ended problem, students earn more interdisciplinary knowledge as well as learning about team operations, project management, communication, writing reports, giving presentations, time management, etc. Additionally, the relevant teaching resources, such as the interdisciplinary and internationalized courses, could be integrated to shape a completed expertise knowledge system for students engaging in the joint programs. In order to achieve the goals mentioned above, new teaching approaches towards design-based learning (DBL) could be applied as an option in the Sino–Australia joint program for progressing the manner and level of teaching and learning from rather superficial to deep.

2. The DBL Pedagogy Used Worldwide in Engineering Education

2.1. Worldwide Practices of DBL Pedagogy

Design-based learning (DBL), also known as design-based instruction, is an inquiry-based form of learning, or pedagogy, that is based on the integration of design thinking and the design process into the classroom in general as well as professional education. DBL environments can be found across many disciplines, including those traditionally associated with design, as well as others not normally considered design related. DBL is used as a pedagogical approach to teach 21st century skills, such as communication and collaboration, and foster deeper learning. Due to the remarkable effects on enhancing the students' capabilities in learning, the teaching approaches towards DBL or problem-based learning (PBL) have usually been applied in the engineering education as an internationally recognized effective methodology. PBL is focused around problems, while project-based learning (PjBL) is focused around projects; DBL is focused more on design activities implemented through projects as a learning vehicle. For more than a decade PBL, PjBL and DBL have been implemented in various teaching and learning approaches to meet the needs and contexts of the various educational programs.

Within the PBL process, other variations on the methodology have been developed and implemented in the classroom. Eberlein et al. [5] presented the characteristics of three common methodologies used in teaching science, comparing and contrasting them in order to enable a possible choice or combination in particular situations of learning processes. The three methodologies that these authors presented are: problem-based learning or project-based learning (PBL), process-oriented guided inquiry learning (POGIL) and peer-led team learning (PLTL); all of these approaches focus on enhancing active learning and are student-centered. Helsingor et al. [6] created a program for engineering students, the European project semester (EPS), with groups of international students who work carefully on selected interdisciplinary projects to develop abilities and specializations, in addition to intercultural communication and teamwork skills. Jongeneelen et al. [7] coordinated a support group for developing teaching skills for lecturers at Eindhoven University of Technology (TU/e) within a concept of technological innovation called design-based learning (DBL). According to Newsletter [8], PBL had been used as the most important means of integrating scientific fundamentals within higher education focused on engineering. By using DBL, the learning activities were not a linear process in enhancing student learning. A DBL-based teaching approach could lead students to explore multiple solutions for one problem. That means that the students could probably choose various approaches while various student groups brainstorm on the same problem and would most likely suggest multiple solutions.

Teaching methodologies towards DBL and PBL were widely used in Chinese higher education in engineering disciplines. They are used to enhance the autonomous learning and collaborative ability of students in the engineering courses [9,10]. Some experiments have compared between research universities and vocational colleges. Results indicated that DBL and PBL pedagogy is more effective in cultivating learners' innovative ability and training engineering skills [11,12], whether at research universities or vocational colleges. With the dramatic development of internationalized cooperative education in China, the globally used DBL pedagogy is playing an increasingly significant role in training professional talents with the global vision.

2.2. Advantages of the International DBL Pedagogy in the Engineering Education

Design-based learning (DBL) is an active, collaborative and integrative teaching methodology; it can be used in almost all engineering courses established in the joint programs in engineering fields. The teaching methodology towards DBL allows students to acquire a range of skills, such as teamwork spirits, intercultural competences, internationalized communication, continuous self-learning, project and team management, ethical, social and environmental responsibilities, etc. Furthermore, the skills trained by PBL are also consistent with the professional capability of performing projects in an innovative way in real companies, such as building specialized and cooperative environments for innovations, developing fundraising projects for research using various financial supports, and seeking technological development and innovations [13].

Design-based learning is a self-directed approach where it initiates a student learning process to design creative and innovative practical solutions. DBL is an effective vehicle for learning, which is centered on a design problem-solving structure adopted from a combination of problem-based learning (PBL) and project-based learning (PjBL) [14–16]. Design projects are used to motivate and teach team-based skills in a studio-based learning environment. Unlike problem-based learning and project-based learning, DBL is a self-directed learning approach, which opens up the learning process for students in collaborative learning environments. In PBL, the role of the teacher is to act as a supervisor of the learning process. Problem solving is the component of the problem-based approach; student learning focused on problem scenarios rather than discrete subjects and the selection of the problem is essential. Whereas PjBL is predominately task oriented and facilitators (teachers) often set the projects. In this scenario, students need to produce solutions to solve the project and are required to produce an outcome. Teaching is considered as an input directing the learning process. The project is open-ended and the focus is on the application and assimilation of previously acquired knowledge.

Design-based learning education is a form of project or problem-based learning in which students work in a team to gain knowledge while designing a solution (object or artifact or report) that is meaningful to the students. It involves collecting information, identifying a problem, suggesting ideas to solve it and evaluating the solutions. Once students have chosen the problem to focus on, they design a solution to solve it. Finally, the students receive feedback on the effectiveness of their design both from the facilitator and from other participants. Design-based learning is especially used in scientific and engineering disciplines [17–20]. Studio-based learning environments assists the curriculum to support students being hands-on in their work, in addition to using problem solving skills, engaging in collaborative teamwork, creating innovative designs, learning actively and engaging with real-world problems [21,22].

With the technological innovation of DBL, a project in mechanical manufacturing was developed for the teaching skills of lecturers at Eindhoven University of Technology (TU/e). The pedagogy for shaping the students' engineer competence at TU/e is framed in the assessment criteria designed for DBL in Bachelor's and Master Curricula [23,24]. The graduate criteria are defined by seven competences of students; those are: (1) competence across several scientific disciplines; (2) competence in researching; (3) competence in designing; (4) a scientific learning approach; (5) fundamental intellectual skills; (6) competence in cooperation and communication; and finally, (7) overall consideration in eco-social issues. Every joint program should be assessed against the competent criteria mentioned above under the DBL framework.

3. Teaching Methodology towards DBL for Sino–Foreign Joint Programs in Engineering

3.1. Seven Principles of DBL for the Engineering Joint Courses

Due to the practical requirements of the engineering programs, some teaching methodology has to be adjusted to meet the needs of curricula in Engineering where DBL is more appropriate. DBL plays a significant role of developing technical knowledge by effective self-learning. It also facilitates the development of students' abilities of conceiving models for solving multidisciplinary problems, as well as improving the students' communication ability in the internationalized teamwork [25]. The skills of analyzing, modeling, testing and technological application are trained by DBL projects for shaping the students' profiles of competencies in Engineering.

The seven principles methodology of PBL has been adapted within DBL as a working methodology to develop engineering problem-solving competence [26]. The general seven jumps of DBL theory is illustrated in the Figure 1.

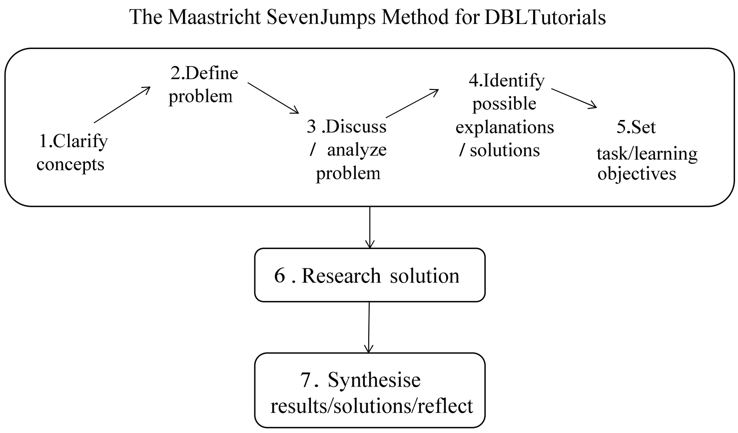

Figure 1. The general seven principles methodology of design-based learning (DBL) for the joint engineering programs.

The DBL teaching goal is to guide students solving an engineering problem as a starting point, and create a product, a material, a set of processes, or a system as an end point. After the learning activities beginning with an engineering problem, the students engage the project following the seven jumps of DBL. Students shall design the end product or complete the final tasks through creating a solution plan to manage the project process.

In the actual performance, a DBL project typically consists of a teaching process that will take 8 to 13 weeks in a semester depending on the teaching needs. Through integrating the distinctive knowledge in Sino–foreign courses in various learning processes for various learning goals, multiple topics and interdisciplinary knowledge domains can be reconstructed in order to shape a more extensive, integrated and flexible knowledge system for the students involved in the joint engineering programs.

3.2. Implicit Meta-Cognitive Teaching in DBL for the Engineering Joint Courses

The DBL methodology applied in the engineering joint courses actually has a clear objective to stimulate the students' learning course. One of the primary tasks of DBL is to guide and facilitate the learning process through supporting students to integrate and apply their knowledge and findings [27]. As an active learning strategy, DBL supports an implicit meta-cognitive methodology via diverse teaching approaches, such as teamwork, self-learning, group discussions and oral presentations. Due to the implicit teaching role of the tutor, DBL projects based on meta-cognition actually promote communications among peers and reflections on one's own experiences [28]. The meta-cognitive process illustrated in Figure 2 can be simply considered as a reflection technique based on questions or "nondirective comments", such as "What do you think about it?", "Why do you think that it is fine like this?" or "does anybody have another opinion about it?".

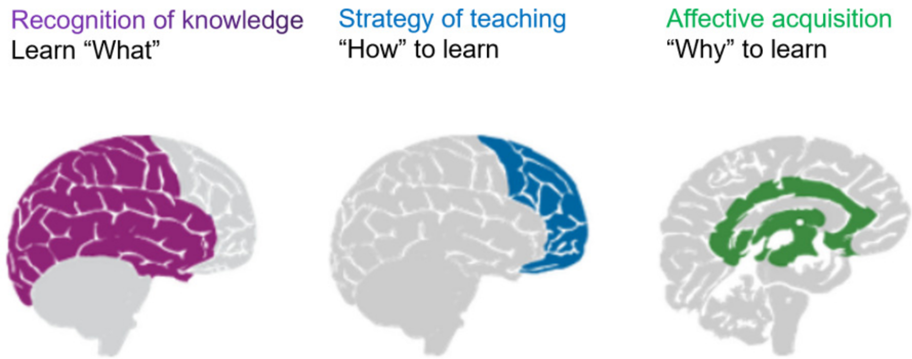

Figure 2. Meta-cognitive learning process based on questions.

The meta-cognitive learning and teaching process actually includes 3 operational stages. (1) recognition of knowledge (learning "what")—we gather facts and categorize what we see, hear and read. Primary recognition tasks are to identify the issues in engineering subjects. (2) Strategy of teaching (how to learn)—give advice to plan and perform the project. How to solve the issues and organize and express ideas are the strategic tasks. (3) Affective acquisition (why to learn)—enable learners to understand the learning goals, how to motivate learners and how to use the acquisition in engineering practice. The proposed project provides a suitable course to support learners to go through all seven steps of DBL in group work. This teaching model facilitates the students' learning of how to establish the goals, select the appropriate strategy among a variety of possible choices, work out the plans, and subsequently analyze the implementation results of the plans. Additionally, the tutor will save the time spent on the lectures if using the implicit meta-cognitive teaching methodology in the engineering joint courses [29].

In the practice of DBL, the tutor indirectly gives students guidance through offering self-learning resources and organizing discussions, presentations and exchange meetings. Hereby the tutor plays a significant role of implicit supervisor in the various jumps of DBL. Students acquire the specialized knowledge by themselves with the DBL method and learn how to apply the knowledge they gained in the course in the practice of the project. Therefore, their self-learning competences are promptly developed by the DBL teaching model. That means an adequate methodology on developing the implicit meta-cognitive competence for engineering learning. The implicit meta-cognitive competence is crucial to the learners since it teaches students how to work in groups, how to make a presentation and how to write a technical or academic report. Besides these professional skills, students also receive training in different kinds of technical skills, like the use of various software types (MATLAB, CAD, CAM, FEM) and other tools that can used to solve problems.

How to improve learners' meta-cognition skills is key to the engineering teaching methodology towards DBL. A study used a hidden Markov statistical model to simulate the success rate of learning tasks through changing the implicit parameters of meta-cognition during the learning course. The experiment conducted by Chinese scholars indicated that repeated exercises can improve learners even though the frequent use skills of meta-cognitive consciousness can achieve much better learning results for learners [30]. In summary, the international teaching methodology towards DBL with the remarkable advantages and performances is adequate for the Sino–foreign joint programs in Engineering.

4. Case Study on the DBL Teaching in the Manufacturing Technology Course

4.1. Goal Establishment of the DBL Project in the Joint Course

As a successful study case at WUST, the DBL pedagogy is used in teaching the Manufacturing Technology course. Major specialized courses in the Sino–Australia joint program include a majority of courses in the field of Mechanical Engineering, such as Theoretical Mechanics, Material Mechanics, Machinery Principles, Modern Design Method, Machinery Design, Electrotechnics, Mechanical Engineering, Testing Technology, Mechatronic Transmission Control and Manufacturing Technology. Among them, the Manufacturing Technology is the most important specialized course with a higher practical requirement. It is key for students to obtain primary knowledge and skills about manufacturing and processing technologies towards various engineering materials. It is established as a core specialized course to cultivate students' competence in Mechanical Engineering.

Students take 72 h during the course for 4.5 credits. A total of 36 h are given by Australian lecturers who travel to WUST for this program, and the other 36 h are given by WUST faculty in full-time English. Australian DU lecturers are responsible for giving lectures about the processing knowledge of non-metal materials. WUST lecturers are responsible for the metal processing. They use the DBL pedagogy in the joint course through establishing and completing a joint project of process planning for a given part made of various materials. Through this DBL project of process planning, the knowledge is taught to students and practical experiences are learned independently. Since the theoretical lectures and the DBL project are performed simultaneously, students always seek the solutions through thinking and search by themselves while they encounter various problems in various fields, from material choice to clamp design. Each knowledge point is linked to form a chain of solutions for tackling the problems encountered in the design process. After submitting the processing sheets and equipment design drawings, students will learn all of required theoretical knowledge and practical skills depending on the joint project.

Additionally, the pedagogy towards DBL cultivates a stronger faculty consisting of senior lecturers from Deakin University and WUST. The DBL teaching promotes academic and educational exchanges between Sino–Australian teachers. Likewise, the DBL teaching also promotes the learning communications between the students. Due to its involvement in diverse expertise fields, from material science to processing technology, the project team needs to integrate and use the advanced educational resources from the joint universities. For example, the electronic documents and video on Deakin Cloud are mostly used as a type of advanced teaching resource to improve the engineering educational internationalization at WUST. On the other hand, comparing with the broader knowledge taught by the Australian side, WUST intensifies the teaching in machining of metals and machine tools so that students can obtain more intensive knowledge and skills in detail. DU lectures pay more attention to the engineering properties and the corresponding processes though insufficiently to the methodology of process planning, accuracy computation and equipment design. Conversely, WUST lectures' knowledge covers a relatively narrow scope excluding the processes of polymers, ceramics and composites, which cannot represent the development trend of manufacturing technologies. Therefore, through establishing the joint project and considering various material choices, process planning and equipment design, DBL pedagogy in the joint course can fully use the advantages of both sides to shape the students' completed international competitiveness.

4.2. Tasks, Divisions and Group Collaborations

4.2.1. Assessment 1 of Project Proposal

The DBL-based project is divided into three assessments; the first one is the project proposal, the second one is the oral presentation and the third one is the project report for process planning. Less than eight students in each group will be given a component for which to plan the manufacturing processes. At most 18 groups will be organized for the project.

In the first assessment, each group is responsible for assigning the tasks of the process planning for the given part. Additionally, the group needs to complete the literature review and list the references and technological manuals. In summary, there will be seven major tasks for completion:

1. Task and group choice;
2. Part drawing (10 marks);
3. Annotation of dimensions and accuracy (10 marks);
4. Performance and quality requirements (20 marks);
5. Material selection including descriptions of material structure and property (20 marks);
6. Quantity of output and cost analysis (20 marks);
7. Referencing including using technological manuals (20 marks).

The proposal must be formatted in a professional manner of an academic article using word processing software. Only one report is required to be submitted by each group. Group members shall sign their names according to the order of their contributions.

4.2.2. Assessment 2 of Oral Presentation

In the second assessment, the requirement is to complete a 10-minute oral presentation on an assigned task depending on the topic choice in the first assessment. This oral presentation will be assessed on the following requirements:

1. Content (60 marks);
2. Referencing information correctly (20 marks);
3. Presentation length (10 min ± 1 min) and collaboration (10 marks);
4. Creativity and presentation style (PowerPoint, props etc.) (10 marks).

Additionally, the presentation should include the following main contents:

1. How to process or manufacture the part, namely the process planning, including the material selection on the material structure and properties (20 marks);
2. The positioning analysis and accuracy calculations, namely the quality control (20 marks);
3. The machine selection and the special tool design (the clamp or module or die) for a given operation and satisfying the corresponding accuracy requirement (20 marks).

Detailed requirements of the presentation contents are listed in Table 1.

Table 1. Detailed requirements of the presentation contents.

NO.	Presentation Contents	Detailed Requirements
1	Process Planning Task	Define primary shape of item
		Review shaping processes that can be selected to make item. List and describe each one. Choose and justify process selection to make item
		Discuss and justify need for surface treatment (coating, surface, roughness etc.)
		Draw a flow chart of the manufacturing process
2	Material Selection Task	Description of use/function and cost to buy
		Required properties (constraints and objectives)
		Choice of material and justification

Table 1. *Cont.*

NO.	Presentation Contents	Detailed Requirements
3	Quality Control Task	What properties or features of your component/product are you going to measure or inspect?
		What method are you going to use to measure or inspect these properties or features? How many or how often are you going to measure them?
		Add quality control measures to your flow chart
4	Machine Selection and Special Tool Design	Correct machine selection for the corresponding processes
		Structure design on the special tool for the process with higher accuracy requirement
		Complete the relative positioning analysis, error estimations and accuracy calculations
5	Cost Task (Optional)	Complete material cost for item (show calculations)
		Complete tooling cost for item (show calculations)
		Complete capital cost for item (show calculations)
		Complete overhead cost for item (show calculations)
		Complete an Cs-n curve for the item (show calculations)
6	Quality Management Task (Optional)	Review quality policy from three companies of your choice and then write your own quality policy
		Research and explain one continuous improvement strategy your company will adopt

4.2.3. Assessment 3 of Process Planning Report

In the third assessment, the major tasks include the project report of process planning and the clamp design or module design. The tutor will offer students a manual of design instruction in which 12 general procedures are advised for the process planning and clamp design:

1. Determine the production platform and clear the design task;
2. Check the drawings;
3. Choose the blank and estimate for the total machining allowance;
4. Outline the principal route of the machining processes;
5. Determine the machining allowance for the main processes;
6. Determine the processing parameters (t, s, v) for the main processes;
7. Estimate the labor time for the main processes;
8. Match the appropriate equipment and tools;
9. Fill out the operation bills and accomplish the processing documents;
10. Design the proper clamps and fixtures for the crucial processes;
11. Accomplish the designing illustration and the corresponding calculations;
12. Accomplish the drawings of the clamp assembly and the components.

The first assessment starts at the 2nd lecture on the 1st week, the second assessment at the 2nd lecture on the 2nd week, and the third assessment at the 1st lecture on the 5th week. That means the project towards DBL for process planning takes place simultaneously with the theoretical lectures so that students can learn and inquire in time to ensure the implementation of the project.

4.3. Methods for Learning Manufacturing Technologies

The tutor facilitates or offers more than 24 ideas of machine or appliance parts as the topics of the joint project. Students can also choose other interesting topics for their own projects. Some examples that have completed by graduated students in recent years are listed in the Table 2. Further, the tutor offers the design instruction manual for helping the students to succeed in the process planning, machine tool choices and clamp design, and also offers the module and die design manuals for the non-metal parts designs. The design manual written by WUST faculty and the original textbooks chosen by Deakin University are shown in Figure 3. The tutor and the group coordinator organize the discussion on the proposal, the real fabrications or simulation experiments depending on the process plans, and subsequently give the oral presentation for the progress of the design. The learning progresses are performed step by step towards the target of the process planning project, as demonstrated in Figure 4.

Table 2. Examples for advised topics offered in the joint project.

Proposal Topics of Assessment 1	Oral Presentation Topics of Assessment 2	Report Topics of Assessment 3	Drafts of Parts
Safety helmet	The design of manufacturing processes and equipment for the safety helmet	The design of manufacturing processes and equipment for the safety helmet	
Fork	The metal working process planning for forks and the design of stamping die for blanking and bending operations	The metal working process planning for forks and the design of stamping die for blanking and bending operations	
Plastic bottle	The process planning and the design of blowing mold for plastic bottles	The process planning and the design of blowing mold for plastic bottles	
Connecting rod	The process planning and the design of special clamp for machining the connecting rod of combustion engine	The process planning and the design of a special clamp for machining the connecting rod of combustion engine	
Train rail	The rolling process planning for the train rail and the design of the suspension clamp for the straightening operation	The rolling process planning for the train rail and the design of the suspension clamp for the straightening operation	
Spur gear shaft	The processing plan for the involute cylindrical spur gear shaft and the design of special fixture for tooth shaping processes	The processing plan for the involute cylindrical spur gear shaft and the design of special fixture for tooth shaping processes	
Piston	The process planning and the clamp design for the machining of pistons	The process planning and the clamp design for the machining of pistons	
Child slide	The extrusion and bending processes and the mold design for manufacturing the child slide	The extrusion and bending processes and the mold design for manufacturing the child slide	

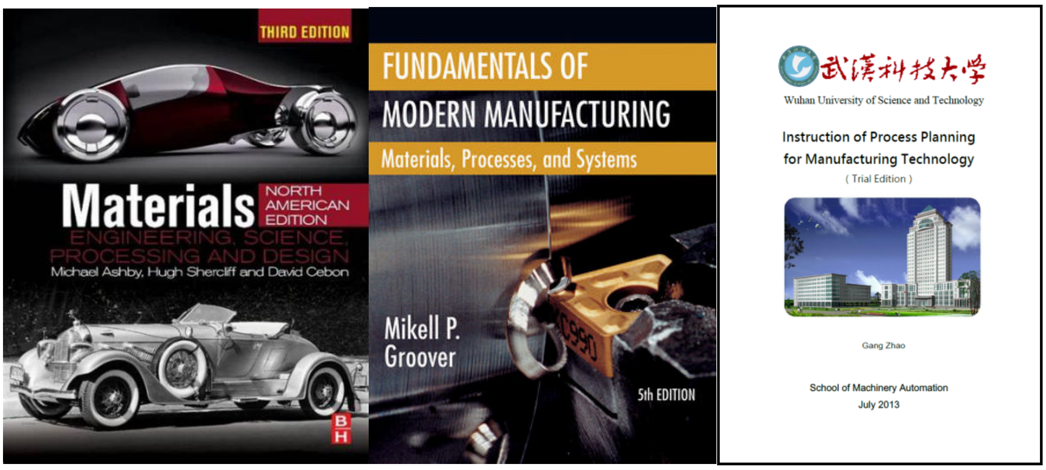

Figure 3. The textbooks and design manual chosen in the joint project towards DBL.

Proposal discussion Process planning Oral presentation

Figure 4. Teaching and learning step by step in the DBL project.

In this project approximately 30 knowledge points are linked, covering the fields of material property, interchangeability, process planning, positioning accuracy, reliability, machine tool and clamp or mold design, etc. All of these knowledge points are taught simultaneously in theoretical lectures in order to answer all questions that might be asked by students during performance of the project. Apart for the theoretical lectures, other learning assignments including assignments in the classroom, experiments in the lab, homework, discussions, and internship in companies are used to consolidate what students have learned in the course. The joint project is not separated to other learning sessions. It is integrated with other learning sessions into the course to form a task-driven method for DBL. Via this DBL project, students learn the knowledge points step by step according to the general learning law. The DBL project helps students build up a complete knowledge framework of manufacturing technology, as well as cultivate the innovative consciousness and innovative thinking in manufacturing technology and especially improve their practical competences.

4.4. Assessments on the Learning Achievements

4.4.1. Assessment 1 of Project Proposal

The first assessment of a project proposal requires two submissions including a proposal report and a part drawing with annotations. The due date is set on the 2nd lecture of the 2nd week. Depending on students' submissions and presentation at the end of each assessment, the tutor assesses each group complying with the evaluation criterions. According to the different training goals, each assessment in the joint project regulates the corresponding criteria in detail as per the following:

1. Part drawing with annotation of dimensions and accuracy account for 20%;
2. Performance and quality requirements of the part account for 20%;
3. Material selection including descriptions of material structure and property account for 20%;

4. Quantity of output and cost analysis account for 20%;
5. References including technological manuals account for 20%.

Group marks are given firstly and subsequently the individual marks are assessed within a fluctuation of ±10 marks based on the group marks. The individual marks account for 6% of the final record of the joint course.

4.4.2. Assessment 2 of Oral Presentation

Likewise, the second assessment of the oral presentation requires the students to prepare a set of slides and give a presentation, both of them in English. In addition, students need to submit a set of processing documents consisting of one process sheet and at least three operation sheets. The due date of this task is on the 2nd lecture of the 5th week. Since comprehensive knowledge relevant to the process planning is required to reveal in the presentation, this second assessment is relatively important in the entire DBL project. The criteria for the second assessment are relatively detailed as listed in Table 3 and the corresponding marks in Table 4.

Table 3. Criteria for the second assessment of oral presentation.

Mark	Criteria	Exceptional	Excellent	Very Good	Good	Satisfactory	Not Satisfactory
60%	Description of the process planning, including the operation selection and sequencing, the machine and tool selection (20 marks)	A thoughtful, insightful and detailed description of the process planning.	A thoughtful, detailed description of the process planning.	A detailed description of the process planning.	A description of the process planning	A description of the process planning but lacking information on the given part	Not done or insufficient detail
	Quality control including the positioning analysis and accuracy calculations (20 marks)	A thoughtful, insightful and detailed analysis of the positioning and accuracy calculations.	A thoughtful, detailed analysis of the positioning and accuracy calculations.	A detailed analysis of the positioning and accuracy calculations.	A description of the positioning and accuracy calculations	A description of the quality control but lacking the detailed information	Not done or insufficient detail
	The crucial operation selection and the special tool design for a given operation and satisfying the corresponding accuracy requirement (20 marks)	Thoughtful and well-justified selection of machine tools and good design of special tools	Thoughtful selection on machine tools and good design of special tools	Thoughtful selection on machine tools and description of special tools	Selection on machine tools and description of special tools	Only selection on machine tools and universal tools but lacking the design on special tools	Not done or insufficient detail
20%	Referencing involving the identification of process applications and future developments (20 marks)	Highly reliable information sources have been used and cited in all instances using a proper referencing style	Reliable information sources have been used and cited in all instances using a proper referencing style	Reliable information sources have been used in most cases and all have been cited using a proper referencing style	Reliable information sources generally used and have been cited or referenced	Not all information used from reliable sources and an attempt was made at referencing	Not done

Table 3. *Cont.*

Mark	Criteria	Exceptional	Excellent	Very Good	Good	Satisfactory	Not Satisfactory
10%	Presentation length and collaboration (10 marks)	10 min. Both students share presentation responsibility equally in a smooth cohesive manner	9 min or greater than 11 min. Both students share presentation responsibility equally in a smooth cohesive manner	9 min or greater than 11 min. One student does majority of presentation in an organized manner	9 min or greater than 11 min. One student does majority of presentation	9 min or greater than 11 min. No evidence of collaboration	Does not meet time length and no evidence of collaboration
10%	Presentation style including grammar and spelling (10 marks)	Exceptionally high standard	Excellent standard	Very good standard	Good standard	Acceptable standard	Not satisfactory

Table 4. Advised marks depending on the criteria for the second assessment of the oral presentation.

Criteria	Exceptional	Excellent	Very Good	Good	Satisfactory	Not Satisfactory
Process planning including the material selection (20 marks)	20	18	16	14	12	0
Quality control (20 marks)	20	18	16	14	12	0
The machine tool selection and the special tool design (20 marks)	20	18	16	14	12	0
Referencing (20%)	20	18	15	14	13	0
Presentation length and collaboration (10%)	10	9	6	4	3	0
Presentation style including grammar and spelling (10%)	10	9	6	4	3	0
Scoring Range	100–90	90–75	75–65	65–55	45+	Anything lower than 45

4.4.3. Assessment 3 of Process Planning Report

The third assessment of the final report needs to submit a set of process planning sheets, design drawings and a design report in an electronic copy. All submissions must be submitted by the end of the joint course, that is, the final lecture on the 9th week. The assessment criteria for the final report and design drawing mainly include the following items:

1. Process planning, accuracy analysis and design notes account for 20%;
2. Calculations and parameter determinations account for 20%;
3. Design background, literature review and references account for 20%;
4. Process and operation sheets account for 20%;
5. Design drawing for clamp or die or mold account for 20%.

The individual marks are assessed complying with the same rule as the assessment 2 and depending on the group marks. The marks of assessments 2 and 3 each account for 6% in the final record of the joint course. The record composition of assessments in the entire course is demonstrated in Table 5 below. The internship in the companies is recorded as another independent course in the same semester, therefore excluding the assessments in the course of Manufacturing Technology.

Table 5. Record composition of assessments and the DBL goals in the course of MT.

Record Composition	Assessments	Record Percentage		DBL Goals in the Course
Usual record percentage 60%	Homework	6%		Enable students to use computer-aided process design for mechanical products and design and manufacture of special fixtures using technical materials such as standards, specifications, manuals, atlases and computer software.
	Experiments	12%		Familiar with basic tolerance measurement methods and measurement tools, master experimental data and measurement error processing methods, have basic mechanical product manufacturing and quality control capabilities.
	Assignments	12%		Cultivate students' competence to analyze and design the manufacturing process of mechanical products, so that they have the ability to research and develop innovative processes and processing equipment. This
	DBL Project	Proposal	6%	Enable students to understand the international technical and economic policies and establish the correct sustainable manufacturing thinking. Learn the new development trends of manufacturing technology. Enable students to precisely demonstrate the process planning and clamp or mold design by the form of oral expression and presentation or other approaches. Cultivate the students' teamwork awareness and the effective communication competence with other team members or in public.
		Presentation	12%	
		Report	12%	
Final exam record percentage 40%	Final exam, closed book	40%		Cultivate students' cognition and application ability of theoretical knowledge in the field of Mechanical Manufacturing, so that they can master the basic theory, knowledge and methods on the process planning for machinery parts and possess the ability to explore the basic theory in the field of Manufacturing Technology.

4.5. *Effects on the DBL Teaching in the Course of Manufacturing Technology*

4.5.1. Outstanding Outcomes of the DBL Project

When the students completed all tasks in the DBL project, they have obtained adequate experiences and skills of using proper manufacturing technologies in engineering practices, not only a set of process sheets and equipment drawings. Figures 5 and 6 exhibit a number of students' outcomes of the DBL project, including the design models and real products awarded by various national competitions. Additionally, several academic articles in the field of engineering written by teachers and students who engaged in the joint program were published in renowned international journals and indexed by the SCI database [31–35].

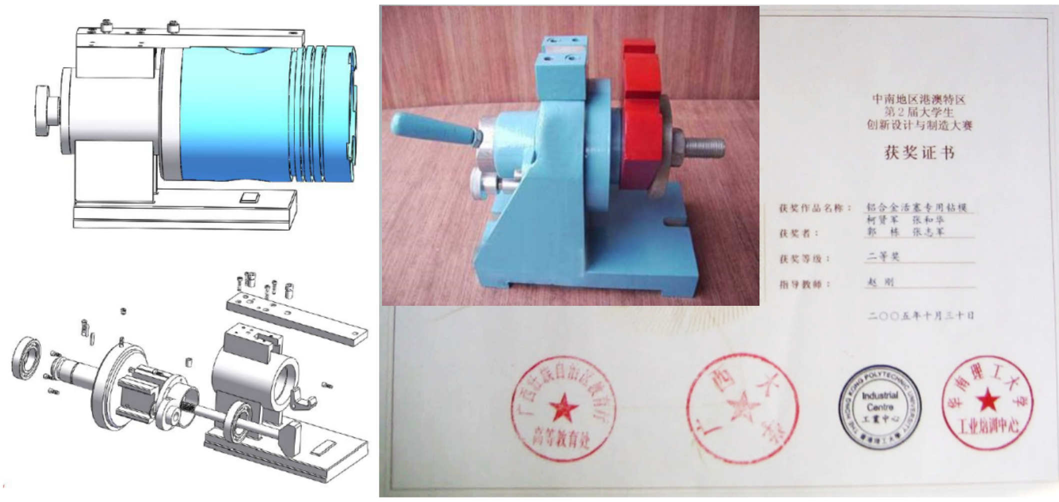

Figure 5. Outcomes of drilling clamp awarded by the Central Southern China Competition of Innovative Mechanical Design and Manufacturing.

Figure 6. Outcomes of magnetic filter awarded by the National Competition of Energy Conservation and Emission Reduction.

4.5.2. Satisfying DBL Methodology in the Joint Course

The survey at the end of the joint course shows students' satisfied attitudes towards the DBL methodology used in the course. A total of 91% of students agreed that the collaborative teaching had motivated them to achieve the learning goals, while 82% of students agreed that the group-based practical activities were most helpful towards achieving the learning goals [36]. Surveys of student satisfaction indicated that the students were for the most part satisfied with the DBL teaching methodology in the joint course of Manufacturing Technology.

4.5.3. Extension of the DBL Methodology in Sino–Foreign Joint Education

Due to the remarkable effects on the engineering education, DBL methodology is widely used in other courses and successfully extended to the entire program in Mechanical Engineering. The contribution of "Reform on WUST Internationalized Educational Modes in Sino–foreign Cooperative Training for Engineering Talents" were introduced to experts, presented at the 8th National

Sino–foreign Cooperative Education Annual Convention (NSCEA) in 2018, as well as the contribution of "Optimization and Implementation on Sino–foreign Cooperative Curricula Teaching System in Mechanical Engineering for Training High-quality Internationalized Engineering Talents" presented during the 9th NSCEA in 2019. Both contributions have won high praises from experts in the field of Sino–foreign Cooperative Education nationwide.

4.5.4. Accredited by Engineers Australia and the China Ministry of Education

The joint program in Mechanical Engineering has been accredited by authorities of Engineers Australia (EA). Such a globally authorized joint program possesses the highest international competitiveness, therefore being accepted by the China Ministry of Education as the first class of the undergraduate admission program. In 2019, the Sino–Australia joint program has successfully passed over the educational assessment organized by China Academic Degrees and Graduate Education Development Center (CDGDC) of the Ministry of Education. Through practicing the efficient teaching methodology towards DBL in the Sino–Australia joint program, WUST cultivates more than 200 high-qualified internationalized talents with the global vision in Mechanical Engineering, who are capable of participating in international affairs and competitions for global socio-economic development.

5. Conclusions

The DBL pedagogy consists of three key sessions, which are the project proposal by the tutor, the meta-cognition on the DBL method, and the objective assessment system. DBL is doubtlessly a universal pedagogy accepted by global educational institutes, and the teaching methodology towards DBL used in the Sino–Australia joint program offers an internationalized approach to the specialized education in Engineering. It actually strengthens the educational cooperation with oversea universities and truly improves the teaching quality of the courses in the joint program.

In WUST teaching practices, the DBL methodology integrates extensive educational resources from Deakin University and other renowned universities worldwide. Due to a common project goal, all knowledge, skills, teachers and students are organized together so that they can complete a design or project-based learning process. That means that the DBL methodology exactly meets the learning requirements of each session in the course. Consequently, the teaching methodology towards DBL successfully addresses the challenge of insufficient educational resources at regional universities like WUST.

The DBL project for the process planning requests that students in one group should exchange their ideas with each other. Especially, students need to communicate with their foreign teachers while they would like to learn more advanced technologies, cross-cultural knowledge, international standards, and other international practices from the cooperative universities. Besides, it is necessary for students in one group to work closely together so that the DBL project can be smoothly done. Therefore, DBL methodology is usually applied in the Sino–foreign joint programs in order to cultivate the future engineers' international communication competences.

The learning process based on the project of process planning involves several courses on materials, engineering graphics, mechanics, interchangeability, reliability, machinery design, etc. These engineering competences are integrated into the learning process in one project so that they can be comprehensively used by students. Therefore, the teaching methodology towards DBL can be used to complete the students' professional knowledge structure and shape their global vision. That facilitates the students' international competitiveness in mechanical engineering. All evidences demonstrate that the teaching methodology towards DBL is successfully applied in the course of Manufacturing Technology and the Sino–Australia joint program in Mechanical Engineering held by WUST. The sustainable model of using the DBL approach with the facilitation of multicultural teachers and facilitators gave a diverse learning experience to students in one particular education system. The possibilities for students to understand their learning context extends towards self-directed learning, teamwork, collaboration, outcome-based learning and research-based learning.

Author Contributions: Project initiation, project planning, research scoping and writing, organising the article—Z.J.; Reviewing the article and analyzing the structure of the article—S.C.; Designing and conducting the course project, analysing the results, and writing—G.Z.; Reviewing the article and worked on appropriate sections of the article—J.L.; Polishing and grammar correcting—Y.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Hubei Provincial Department of Education, grant number 2015224, Chinese Society of Academic Degrees and Graduate Education, grant number 2015Y0507, and the WUST Educational Research Project of "Six Elements" Teaching Mode for International Courses in Mechanical Engineering.

Acknowledgments: Sincere thanks to the reviewers and editors for their comments and suggestions.

Conflicts of Interest: The authors declare no conflicts of interest.

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