ASSESSMENT FOR THE CHANGING NATURE OF WORK:

AIRCRAFT ENGINEERING PROGRAMME

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Publisher's note

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Centre for Work and Learning (CWL) is a research centre of the Institute for Adult Learning. CWL specialises in research on continuing education and training system design and practices. Our research employs a range of methodologies designed to deepen understanding in the challenges and opportunities for learning and development in and across different settings, particularly in relation to work and work environments.

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Preamble

This is ONE of the six cases on assessment practices and the changing nature of work, undertaken by the Centre for Work and Learning (CWL). Each of the six cases highlights different aspects of innovative approaches to assessment, their possibilities and the challenges involved in assessment for, through and at work. Each case suggests different strategies, tasks and/or practices in assessment that can enable **meaningful** and **engaged learning.**

In this case study, we examine the lab-based and practice-oriented assessment of a 3-year Bachelor degree in aircraft engineering programme. The programme is developed by a university based in U.K. and delivered by a training and professional development centre for aerospace engineers in Singapore. We analyse the curricula, lessons and assessment practices of a WSQ module and students' Final Year Project. In particular, the Final Year Project requires application of concepts and skills; suggests real work utility and complexity. It expands the notion of "authenticity" beyond just "real work".

Figure 1: Learning and assessment are entwined

Source: http://www.123rf.com/photo_3706214_stock-photo.html

We think of assessment not as the "test" of what has been learnt at the end of a learning programme, course or set of experiences, but as **judging performance**. We go back to the original meaning of assessment which is "to sit beside". This means that we can think of assessment as working *with* our learners to guide them to meet the required performance. If we understand assessment like this, then learners also need to understand, to know what that desired performance is. In other words we do not hide from them the criteria or expected performance standards. So in other words we are talking about formative assessment – assessment *for* learning. We also acknowledge that assessment of learning – summative assessment – is necessary for accreditation and certification. The question is how we weave these two forms of assessment together. Examples are provided in some of our six case studies. We also discuss this in detail in our full report:

"Assessment for the changing nature of work", available at <url>, as are copies of the other case studies.

In addition to summative and formative assessment we introduce another kind of assessment – sustainable assessment. Sustainable assessment equips learners not just for meeting, but preparing them for what might be required in the future, beyond the course and/or training. It includes "the capacity to evaluate evidence, appraise situations and circumstances astutely, to draw sound conclusions and act in accordance with this analysis" (Boud & Soler, 2016, 402).

These three purposes of assessment and the fact that we investigated assessment in the light of the changing nature of work, mean we also need to think of learning and assessment differently. Assessment serves different purposes including the testing of knowledge and learning yet "testing" need not be the sole purpose. When we think of assessment as only a test of the learning and/or something that happens (sequentially) after the learning, then we are separating assessment from learning and ignoring the fact that learning and assessment are very much in a "dialogic relationship" or **entwined together.** Figure one metaphorically illustrates this entwinement.

In the case studies, we describe what the course/programme/training is about and examine assessment in relation to curriculum design, implementation and the ways in which understanding, accomplishment and performance are achieved. We hope the case studies provide a glimpse into the different ways assessment has been carried out in design, planning and implementation for practitioners, researchers and policy makers. We hope that they highlight possibilities and contribute to new ways of thinking, designing and implementing assessment of, for and as learning. Different conditions and situations (context) will offer different kinds of opportunities for meaningful assessment.

The six case studies are:

- Workplace learning facilitators
- Firefighting: Rota commander course
- Menu change in the food and beverage sector
- Resident doctors
- Aircraft engineering programme
- IT network engineers

Aircraft Engineering Programme

1. Introduction

The Bachelor of Science (Honours) Aircraft Engineering is a 3-year full-time programme designed and awarded by a university based in the United Kingdom. The programme is delivered by a locally-based training and professional development centre for aerospace engineers in Singapore. Upon successful completion of the first two years of the programme, students will receive a 'Foundation Degree' in Aircraft Engineering (FdEng) awarded by the UK university. The third and final year of study is designed as a 'top-up', and culminates in a six-month long individual Final Year Project.

Assessment of learning (summative assessment) in this programme is based on hands-on laboratory sessions as well as written examinations conducted at the end of a module. For the Final Year Project during their third year of study students submit reports and deliver a presentation. Assessment *for* learning (see box beside) is provided by instructors who facilitate the training and guide students in class. Some of the classroom and/or laboratory activities that we have observed include a WSQ module where these students assemble, test, troubleshoot and measure an electrical circuit. Worksheets provide instructions, schematic diagrams and problem-sets. Students learn to read and follow technical instructions, experiment and solve problems. Assembling, testing, troubleshooting, measuring and documenting are fundamental activities in aircraft maintenance work, and they are learned and assessed throughout the module.

In this case-study, assessment clearly serves certification and authentic work-based learning purposes (for certification). The foundation degree/degree programme is designed for initiating and preparing students for work as aircraft engineers and/or technicians, and to gain certification as licensed professionals. Certification and the pathway towards certification are central to the programme, the work of aircraft engineering and the career prospects of the aircraft engineering professional. Certification supports the systematic organization and routinization of work but we also found that certain aspects of the programme such as the Final Year Project and the way learning and assessment have been enacted in the laboratory (for example) create affordances for exploratory

Assessment *for* learning

Assessment *for* learning focuses on participants learning, helping them to know how to improve (Gardner, 2012). It is 'an approach in which the assessment process is inextricably embedded within the educational process, which is maximally information-rich, and which serves to steer and foster the learning of each individual student to the maximum of his/her ability' (Schuwirth & Van der Vleuten 2011, p.478).

Participants need continuous information from a variety of sources about their learning; information that informs what they are succeeding at, and where they should put their efforts to improve and strategies for moving forward (Berry, 2008).

Assessment for learning does not necessarily include grading, assigning marks or noting the learner as competent or not yet competent.

work, problem-solving skills and learning-to-learn opportunities.

Assessment is also shaped by negotiations between pluralist expectations of industry demands and workforce needs for certified workers, the competitive education system, the dynamic and changing nature of the engineering discipline, and students' aspirations and learning goals. These dynamic interactions highlight issues such as: the importance of understanding the industry and profession, and the purposes and values underpinning assessment. In this report we focus on a WSQ certified module and the Final Year Project (FYP) to:

- Provide an overview of the highly regulated nature of aerospace industry and profession in which the foundation degree/degree programme is situated;
- Describe the different features of the assessment design and structure, and practices on the ground in terms of what and how people teach, learn and assess (in an aerospace engineering programme) based on their activities and enactments as well as programme documents and licensing requirements;
- Suggest ways to support sustainable assessment that meet assessment *of* learning, and *for* learning.

First, we begin with a brief description of the aerospace industry and profession in which the programme and its assessment design are situated. This is followed by a semi-ethnographic description of the assessment practices in the WSQ module and Final Year Project that reveal the 'hands-on' nature of engineering know-how, and differences in understanding between instructors and students, which present challenges for thinking about and developing assessment *of*, *for* and *as* learning.

Assessment *as* Learning: Sustainable assessment

Sustainable assessment equips learners not just for meeting current needs but preparing them for what might be required in the future, after graduation. Sustainable assessment includes 'the capacity to evaluate evidence, appraise situations and circumstances astutely, to draw sound conclusions and act in accordance with this analysis' (Boud & Soler, 2016, p.19). The qualities of judgement that need to be developed are similar for students and for teachers; it is only the subsequent ends to which these judgements are put that differ. Key elements of developing informed judgement from the perspective of the students include: (1) identifying oneself as an active learner; (2) identifying one's own level of knowledge and the gaps in this; (3) practising testing and judging; (4) developing these skills over time; and (5) embodying reflexivity and commitment. Sustainable assessment demands that learners make conscious comparisons between self-assessments and assessments by teachers, peers and other stakeholders, and that responsibility for the assessment process must gradually shift from the teacher to the students, because, after graduation, people themselves need to drive their own learning. (Boud & Soler, 2016)

2. The Industry, Certification and Bachelor (Honours) Programme

2.1 The Aerospace Industry

The aerospace industry comprises three primary categories of activities: manufacturing; maintenance, repair and overhaul (MRO), and services such as aircraft leasing and pilot training. More directly relevant to the students and graduates of this programme is the maintenance, repair and overhaul sector. This sector includes work such as servicing and inspection of aircraft as well as aircraft structural repair and conversion. The technical work involved is highly systematic and routinized, and according to aircraft type, manufacturer and operator. The work occurs on the tarmac, in the hangar as well as workshop. It is also highly time sensitive – structured by aircraft schedule, turn-around time, flight hours and aircraft maintenance 'cycles'.

With the continuous development of new aircraft technologies including new materials, aircraft design, engine and avionics, longer lifespan of aircraft and stricter maintenance standards required by international and national air transport authorities and aircraft manufacturers, the demand on and for maintenance, repair and overhaul has been increased. Airline companies in the Asia Pacific region have also expanded their capabilities and facilities to undertake more and increasingly complex maintenance, repair and overhaul operations.

2.2 Aircraft Maintenance: Certification and Licensing

Aircraft maintenance work is tedious, complex and highly controlled by a system of international and national regulatory bodies such as the International Civil Aviation Organization (ICAO), Federal Aviation Administration (FAA) based in the United States, Civil Aviation Authority of Singapore (CAAS), and so on. The work including maintenance tasks, inspection and personnel supervision comes under the regulations of these international and national bodies that set standards and rules for the work as well as issue Air-worthiness Directives (AD). Staff must be licensed for the work they carry out. Hence, certification and licensing are an essential part of the profession and fundamental to the regulatory, operational and training bodies and institutions involved in aircraft engineering.

Aircraft Maintenance Licence such as SAR-66 issued by CAAS is fundamental to all aircraft engineering professionals. This licence has different licensing categories for different types of work, levels of responsibility and expertise based on different systems and aircraft/engine technology. The type of license dictates the kind of tasks that a license holder should and should not do. It is based on different levels of complexity, domain knowledge and responsibility. For example Cat A license holders are authorised to perform simple and *routine tasks* such as *replacement of wheel assemblies, replacement of some cabin items, routine fluid servicing, opening and closing of cowlings and quick access panels*'; Cat B1 or B2 licence holders are authorized to carry out '*diagnosis of defects*', to carry out *'replacement of limited avionic line replaceable units that only require simple tests to prove serviceability'*, to *'work on, supervise and if appropriate issue certificates of release for aircraft structure, power-plant, mechanical and electrical systems*'. Cat C license certifies staff to '*play a management role, be responsible for the issue of the single certificate of release to service for the complete aircraft following base maintenance.* (CAAS 2007)

Hence, career progression and increase in areas of responsibility depend on the level of certification acquired (as much as performance on the job).

As we can see, the licensing requirements structure the complex work of aircraft maintenance into tasks, procedures and roles. We also understand how certification and licensing examinations serve its purpose for work, and as a statement or affirmation of the learner's potential for the work. The licencing structure is reflected in the design and assessment practices of the Bachelor (Honours) Programme.

2.3 Bachelor (Honours) Degree Programme

The Bachelor of Science (Honours) Aircraft Engineering Degree has a component called 'SAR-66 B1.1 'Approved Basic Training' which is recognised by regulatory bodies, Civil Aviation Authority of Singapore (CAAS) and the Maldives Civil Aviation Authority (MCAA). Students enrolled in the degree programme are also required to undertake a series of WSQ modules which are aligned with the national skills framework.

The degree programme is subsidised by WDA of up to 70% course fees for the two-year foundation course for Singaporean citizens and Permanent Residents. It offers opportunities for 'pre-employed' students to obtain licensing qualifications within the aerospace industry, and for licensed aircraft maintenance technicians to obtain an academic qualification and recognition of their training as well as experience. The degree programme developed by a UK university in collaboration with an aircraft engineering company based in the UK uses a 'Foundation Degree' framework[1], and it is accredited by the Royal Aeronautical Society, UK.

In Singapore, the Aircraft Engineering Bachelor of Science (Honours) Degree programme is obtained in two phases. The student undergoes a two-year Full-time Foundation Degree in Aircraft Engineering before qualifying for the Aircraft Engineering BSc (Hons) top-up year. The BSc (Hons) top-up is done in one year for full-time students and two years for part-time students. The Foundation Degree incorporates three elements: UK university's academic modules, the SAR-66 licensing modules and the 'Aerospace WSQ modules' (the WSQ modules are unique to Singapore). The UK academic modules and SAR-66 modules are overlapping in some theoretical and practical training aspects. The SAR-66 modules extend

[1] The original purpose of the programme was to solve the challenges of vocational training and development within the aircraft engineering industry in the UK and in a UK educational context. In the UK, the programme is designed as a 'work-based degree' which has both educational institution provision and work placements. The programme was designed to meet employer needs, fulfil industry requirements and as '*a route to help the (UK) government achieve its target of attracting over 50% of the adult population into higher education'* (Guile 2011, p.245).

the workshop and hangar training including on-the-job training in an actual operating environment.

Theoretical modules include ‘Mathematics and Physics for Practitioner Engineers’ and ‘Electrical Engineering Fundamentals’ as well as a range of system-based subjects like ‘Aerodynamics and Aircraft Electronic and Digital System’, ‘Propulsion Systems’, ‘Avionic Systems’, and others. These modules cover the fundamental knowledge, concepts and thinking skills in (Aircraft) Engineering such as problem-solving and understanding of the approach towards aircraft systems that focuses on (work) processes, (optimisation) methods and (application of) concepts. The WSQ modules take a more *task-oriented* approach that focuses on work-based practices including ‘Perform Basic Aircraft Safety Practices and Documentation’, ‘Perform General Engine Workshop Practices’, ‘Inspect Engine Component Parts’, ‘Disassemble and Assemble Engine’.

In the final or ‘top-up’ year, students undertake more generic and aircraft industry related modules like ‘Air Transport Economics’, ‘Aircraft Maintenance Operations’ and ‘Aerospace Technology’. The 6-month long individual Final Year Project (FYP) is a key module during this ‘top-up’ year that aims to ‘*put what the students have learned over the years into good practice*’ (DaWei, programme co-ordinator). The elements and assessment of the Final Year Project will be discussed in greater detail later.

The opportunities for students to develop proficiency in the field of aircraft engineering/maintenance are tremendous. Experiment-based studies done by researchers such as Sherri Gott (1998) who worked with aircraft engineers to develop learning strategies that “accelerate acquisition of problem-solving and trouble-shooting skills” for high-tech jobs (ibid, i) are informative. Gott’s “cognitive performance model” provides instructional inputs, and criterion for performance and assessment “targeted at the internalized processes and concepts that lie behind the successive approximations of expertise” (ibid, 3). We shall discuss how Gott’s study illuminates areas for improvement in the next few sections. .

2.4 The Assessment

The primarily summative assessment in the programme modules is carried out at the end (of a class and/or semester), and it comprises ‘theoretical’ and ‘practical’ components. This is spelled out in the programme handbook:

- Courses are assessed by written examination and practical assessment.
- Students must meet attendance requirement before they are eligible to sit for a particular examination.
- For CAAS approved course, the attendance requirement is 85%.
- Passing mark is 75%.

The examinations for the modules typically comprise a written paper and Multiple Choice Question (MCQ) components. Students can also take examinations administered by the Civil Aviation Authority of Singapore (CAAS) in order to qualify as licensed aircraft technician and practitioner. They do this on their own initiative. There are eleven subjects in the CAAS examinations which are closely related to what the programme covers.

The assessors and Final Year Project supervisors are also instructors in the programme. They work to ensure that students graduate with competencies or the necessary skills, dispositions and learning capacity to perform the role of an aircraft engineer and/or technician. The professional competency or ‘knowing’ is about developing professional judgment, and there are opportunities to think about and design assessment practices to facilitate and/or enable it (see also Gott 1998):

> *'As engineers over time I think if one has the basics, he should be able to find solutions to a problem. The good thing about aviation is that there are trouble-shooting manuals which can guide you along the way. This may entail that you replace some parts to test if the problem can be resolved. It's a bit like doctoring: you look for symptoms and you prescribe a solution. You may not get it right 100% but most of the time it should work. The more difficult defects would require high level of experience to resolve, after all, not every possible solution can be thought of and written down by the manufacturer.' (Da Wei, programme coordinator).*

Engineering as a system of knowledge is succinctly expressed by Da Wei as a 'risk technology' and 'preparedness technology' (Samiman-Darash 2013) which relies on the ability to identify and detect 'symptoms' or defects, and application of solutions around known and calculable risks documented in manuals and/or embodied in experiences of the engineer. It is also a holistic practice that involves deduction, testing or experimenting, and judgment-making (akin to medical diagnosis and/or practice). All these could be more readily expressed in the programme documentation; rather the programme documentation refers to 'Basic', 'Elective' and 'WSQ' modules. However, we observed holistic practices being *enacted* in the teaching and learning session that we observed in a WSQ module. At a more detailed level the aims of the Final Year Project also reflect a more holistic approach:

> ***Aim***
>
> *The aim of this module is to develop a student's ability to:*
>
> - *Study a topic in depth, critically reviewing work in the same or allied fields in the process.*
> - *Apply analytical, experimental and computing skills to the solution of aircraft maintenance-related and/or engineering problems.*
> - *Collect, interpret, critically evaluate and use data.*
> - *Communicate clearly and succinctly; orally, graphically and in writing.*
> - *Work independently.*
>
> ***Learning Outcomes***
>
> *On successful completion of the module, students will be able to:*
>
> - *Investigate or review a specified topic according to given guidelines with minimal guidance.*
> - *Obtain accurate, relevant data from a variety of sources using appropriate methods.*
> - *Draw reasoned conclusions from the analysis of data and present evidence based arguments to support them.*
> - *Present data, reasoned arguments and evidence orally and in written form to specialist and non-specialist audiences.*
> - *Demonstrate that they are capable of using their own initiative and working independently.*
>
> *(Final Year Project - Module Guide 2015-16, p.1)*

The 'aims' and 'learning outcomes' – even though specifically written for the Final Year Project, nevertheless, provide an opportunity for the delivery of a holistic programme and/or practice that transcends knowledge typologies, job roles, functions and tasks. The holism is not only expressed in Da Wei's reflexive statement about engineering and captured in the Final Year Project Module Guide but also enacted during the teaching, learning and assessment session in a WSQ module/class that we have observed. We suggest that holistic practice could be made more explicit, better reinforced and enabled through sustainable assessment, which will be discussed further in the later sections.

3. Assessment of and for Learning

In this section, we focus on how the assessment design and assessment practices enable or constrain learning, specifically opportunities/affordances for learning in terms of what and how students learn. Here, we examine and observe classes in a WSQ certified module and the Final Year Project. WSQ certified modules are an important work-based component in the programme that attempts to incorporate work-oriented and hands-on practice into the classroom. On the other hand, the Final Year Project is a cumulative exercise that aims to let students put into practice what they have learned throughout the years. The Final Year Project is defined by the notion of ‘independent learning’ which enshrines the spirit of taking responsibility for one’s work and learning.

3.1 Class in Session: A WSQ module

Work-based modules in the ‘Foundation Degree/Degree’ programme such as this WSQ module, ‘*aims to provide the learner with the necessary skills, knowledge, safety precautions and documentation…*’ (National Competency Standard, WSQ Framework: Aerospace Industry) to perform actual work tasks such as testing, measuring and inspecting various electrical components commonly found on an aircraft. These modules may not necessarily add/or contribute directly to the licensing certificates required in the aircraft engineering profession but learners gain some basic knowledge and skills. Instructors with decades of professional experience attempt to expose the students to some of the values of the profession such as accountability and responsibility. These are not necessarily ‘teachable’ in a classroom setting or captured in the programme documentation but are conveyed through the instructors’ conduct and their close guidance of the students’ work during class session. Based on our participation and observation at two sessions of a WSQ module, we report on the learning affordances that an instructor has created through summative assessment, and the students’ participation in this learning.

The WSQ module ‘Perform Electrical Measurements’ is a four-day in-house course that aims to equip learners with the skills and knowledge to use electrical measuring devices to carry out basic measurement and inspection of electrical components, wires and cables found in an aircraft. The module is divided into three ‘Practical Modules’: PM77-1 Measure Voltage, Current, Power, Frequency and Phase Sequence (Electrical Parameters), PM77-2 Check Electrical Serviceability of Basic Electrical Components and PM77-3 Check Serviceability of Wires and Cables. The assessment includes hands-on sessions such as assembling and trouble-shooting an electrical circuit and making the actual circuit work, and a final written examination at the end of the four-day course.

The ‘Practical Module’ PM77-2 Check Electrical Serviceability of Basic Electrical Components is divided into two sessions: a ‘theory’ and ‘practice’ or hands-on class is conducted in the morning, and the afternoon is reserved for assessment. The instructions are methodical and systematic. In accordance to the ‘Objective/Performance Criteria’ of the ‘Learner Guide’, the instructor highlighted the key ‘learning objectives’ as follows: know how to test-check and operate the multi-meter; identify common electrical components such as circuit breakers, switches, capacitors, resistors and solenoids, and measure the values (such as resistance) on these components using the multi-meter.

The 'Learner Guide' comprises a booklet (or a set of notes) that the instructor went through with the students in a lecture style format in the morning. It was meant to familiarise students with the various electrical components and measuring devices like the multi-meter. These components and devices were distributed to the students, and they were given a series of procedures and tasks to be completed (see Appendix 1: Learners Guide). The lecture introduced students to the common electrical components and instruments. These components and instruments were distributed to the students, which kept them engaged with their hands, eyes and ears. In the afternoon, the students were given a problem-set to be solved based on an electric circuit which they had to assemble, and this constituted the summative assessment (see Appendix 2: Assessment Record).

3.1.1 Formative-Summative Assessment

For the afternoon session, the students were required to build an electric circuit and used it to solve the problem-set. Instructions and information were provided for the students to build an electric circuit and solve the problem-set (see Appendix 2). The activity of building an electric circuit provided plentiful opportunities for feedback through 'dialogic inquiry' (see box below) where the instructor engaged the students in a continuous process of questioning that lead to their own further investigation and eventual discovery of the solutions. Instructions to build the electrical circuit on a "bread-board", to measure and calculate the electrical values were provided. Working in groups of three, the students (they were in their first year of study) were required to demonstrate and explain to the instructor how the board circuitry comprising of a relay, 2 LED, power supply and a switch - worked. They were also asked to measure and compute the resistance value of the relay and LED components in the circuit. While the circuit diagram which they had been given to build might seem straightforward enough (just follow instructions and the diagram), each group encountered different kinds of

Cognitive Performance Model

Sherri Gott's (1998) study on United States Airforce engineers who were learning how to problem-solve and trouble-shoot complex fighter aircraft systems is helpful to think about how to improve the learning experience for these aspiring aircraft engineers. She develops the idea of "cognitive modelling" that "makes *explicit* the forms and utilities of knowledge that may otherwise go unobserved, untaught, and therefore unlearned" (Gott 1998, 26). In Gott's "multicomponent cognitive model", experts or Master technicians provide direct inputs into the instructional system that correspond with their "internalized procedural representation" (ibid, 19) or heuristic model addressing "how-it-decide-what-to-do-and-when" or "dynamic, opportunistic reasoning" (ibid, 8), and they provide close coaching during problem-solving to learners with "hints, explanations…missing pieces of knowledge" (ibid 20). The cognitive model enables "manipulation experiences" for learners to develop *inferencing skills* or the capability to infer procedures and establish cause-and-effect relationships.

problems during implementation. Problems and mistakes such as wrong connections, misalignment or wrong placement of components, and faulty parts besotted the groups and no one got it right the first time.

In their groups, the students were guided by the instructor with the trouble-shooting. The experience was scaffolded in such a way that led to the students' self-discovery of the problems and mistakes they had made. This process of self-discovery is a strong pedagogical strategy that necessitates continuous feedback from multiple sources. The process could be documented and developed into a cognitive or heuristic map following Gott's study (1998). The instructor used 'dialogic inquiry'[2] or questioning where learners were assisted in tracing their steps/procedures and lines of thought/thinking, and questions were used to get them to think analytically. Here, instructors probed students by asking questions like which component was not working; why was it not working - was the component faulty or was the connection made wrongly. The students were required to repeatedly demonstrate the assembled circuit to the instructor, and they were encouraged to investigate, identify and rectify the problems.

Via the process of dialogic inquiry or questioning and students' demonstration of their assembled circuit, they were guided through the trouble-shooting process: noting the symptoms of the problem; tracing the steps (of assembling the circuit); identifying and verifying the issue/problem; isolating the cause of the problem; repairing or replacing the faulty component; checking that the problem had been resolved, and following-up with a reminder to prevent future problems. The students went through this reiterative process of demonstrating and explaining (to the instructor) how the assembled circuit worked, questioning and investigating with the instructor at least two to three times before they finally got their assembled circuits to function. The students were moving around, checking with other groups, talking and helping each other out with their work. There was energy, buzz and a lot of focus in the class/laboratory. And the students were exhilarated when the circuits worked and they could see the LED bulbs lighting up and the readings generated by the multi-meter.

3.1.2 Feedback

At the end of the afternoon session, the instructor concluded with a debrief where he explained the 'correct' circuit diagram/chart and highlighted those common mistakes the students made. The students then filled up or corrected their answers

[2] 'The term 'dialogue' most typically refers to face-to-face interaction using the resources of spoken language. This is certainly the mode in which dialogue is first experienced and it remains the most ubiquitous and versatile. However, the means for knowledge building are not limited to speech. On one hand, the solving of problems of a practical nature often depends as much on the coordination of skilful action as on speech and, on the other hand, theoretical knowledge building may be carried on across time and space through a dialogue that uses writing and other visuographic modes of representation (such as images, drawings, diagrams etc.). Across all these modes, however, two features of the dialogue that support knowledge building are paramount: responsivity and the attempt to achieve enhanced understanding. By pursuing this line of argument further, it also becomes clear – as Vygotsky argued - that a similar sort of dialogue can take place when one is alone, using the resources appropriated from engaging in dialogue with others.' (Wells, G. 2000, p.70).

in the problem-set (the summative assessment), and the instructor went from bench to bench to answer their queries and help them with the calculation.

The afternoon summative assessment turned out to be a highly *formative learning* experience with continuous feedback in the form of:

- student demonstration of the assembled circuit,
- dialogic inquiry or questioning, and
- experimenting and working with the components and instruments.

Here, learning is engendered through activities like following instructions and filling-up of the worksheet, assembling and testing of the circuitry, interacting with their peers and the instructor. Students are given the opportunities to discover and communicate what is expected (of them), and then act according to those expectations. Students use multiple avenues to gain feedback: checking the worksheet instructions and schematic diagram, using the testing instrument to gather readings (or null readings), observing the components e.g. LED light, and engaging with the instructor. Observing, participating, experimenting and talking are crucial for students to complete the tasks and problem-set. The multiple avenues of obtaining feedback constitute important features or characteristics of formative assessment. They demonstrate what Vygotsky argued – *'that a similar sort of dialogue can take place when one is alone, using the resources appropriated from engaging in dialogue with others'* (Wells 2000, p. 70).

3.1.3 Authentic Assessment

Authentic assessment involves a focus on:

- performance (Darling-Hammond, 2014);
- students using and applying knowledge and skills in real-life settings (e.g. simulation of role play of a scenario, completion of a real-world tasks or assessment in a workplace setting) (teaching.unsw.edu.au; Mueller, 2016)

As such it involves higher-order cognitive activity and the collection of direct evidence of performance (Darling-Hammond, 2014; Mueller, 2016; teaching.unsw.edu.au).

The multi-column worksheets (see Appendix 1 and 2) which the students have to complete and 'sign-off' mirror the real work documents[3] with a strong emphasis on maintaining good documentation and accountability. These worksheets become a source of formative assessment where the instructor insists that students write their findings clearly and sign off beside their entries. The instructor explains the reasoning behind the worksheets and shows the students a sample of the real work documents.

There is also a strong emphasis to check the 'calibration date' of the instruments such as the multi-meter: the instructor constantly reminds the students to check and

[3] There are two main types of documents used in aircraft servicing work – one is called a 'Planned Worksheet' which details the work to be carried out for the day such as the checking of electrical components on the aircraft, and the other is called 'Inspection Sheet' - a checklist covering the overall health of the aircraft electrical system. These procedures and instructions for servicing are detailed in the aircraft maintenance manual.

ensure the validity of the instruments that they would be using at the workplace even though the instruments used in class/laboratory are past their calibration dates. The lesson combines the 'know-what' of electrical components and their physical properties with the 'know-how' of using instruments to measure these properties, and the emphasis on checking and validating these instruments.

3.2 Final Year Project – Holistic Assessment and Transparency of Purposes and Assessment Criteria

The individual Final Year Project (FYP) is a culmination of a student's learning and understanding of aircraft engineering s/he has developed over the course of the programme (see *Appendix 3: Students' Final Year Project* for examples of what they have learned and discovered in the course of the project). Doing well for the Final Year Project contributes significantly to the type of Honours degree earned/awarded; this matters to these students who are entering a competitive aerospace job market. The aims, learning outcomes, project schedule, requirements and assessment criteria are explicitly stated in the FYP Module Guide, and succinctly summed up by Da Wei, the programme coordinator as '*putting into good practice what have been learned*'. Working on a topic of their choice, students are supposed to demonstrate the knowledge and skills gained from the programme, and show that they 'truly are an independent learner' (Module Guide, p1). The Final Year Project is also meant to be an artefact of the students' employability as a showcase of his/her professional competency to potential employers. In identifying and designing a project, students are advised to 'value-add':

> *'Something new must come out of the project. It is not good enough to choose a project that only requires you to read about (research) something and then write about it. Simply collecting data (in the broad sense of the word) and presenting it without adding anything new to it is what in the words of Steve Barnes (UK Individual Project Module Leader) call a 'school project'. School-style projects will not attract good marks. You need to be critically evaluating and analysing data (all forms – not just numbers), making judgments and decisions, presenting and contesting claims and arguments, presenting and questioning evidence' (Module Guide, p4).*

The notion of 'value-add' suggests holistic assessment that contributes to the student's ability to critically evaluate and analyse data; exercise judgment; rationalise and communicate the processes of and results from the project. All these elements are expressed/captured primarily in the 'learning outcomes' of the Final Year Project. The evidence for holistic performance is mainly provided in the form of three artefacts with different weightages attached:

- Interim Report 20%
- Final Report & Log Book 60%
- Project Presentation 20%

Speaking with the programme coordinator Da Wei, we understand how the Final Year Project is also intended to inculcate 'independent learning' (listed as a 'learning outcome' in the Module Guide, p.2). The Final Year Project and the holistic assessment it engenders not only aim to 'put what they have learned together'; 'put theory into practice' but also to demonstrate commitment, responsibility and independence or as Da Wei put it humorously, to 'turn boys into men':

> *'Once the students get into the Final Year Project, there is no chance to slack. They have to really start thinking because now the ball is in their court – if they slack/sleep, nothing comes out and they are dead. So in a way I see the Final Year Project wakes them up and many of them (got awakened) – you will find the shift in their behaviours. The behavioural changes particularly from Year Two to Year Three are something I notice from my own observation. Character change I tell you. Totally different: they become more responsible, more hardworking, and they are all on their own now. They will stay back till very late to work on the FYP, and it is something I do not often see when they are in their First and Second Year. And I have always been thinking what is it that makes them different and I think the FYP, besides the lessons in the Third/Final Year that makes them different. Really turning from boys to men.' (Da Wei, Programme Coordinator).*

The purposes as outlined by the programme coordinator are important aspects of holistic, authentic assessment. All these implied purposes could be made more explicit in the curriculum documentation and in the assessment criteria mainly to reduce and/or allay concerns about fairness and validity of the assessment. In addition, transparent criteria for what constitutes a final year project could also enable shared understanding of purposes. For example, gaining sign-off on the purpose and plan for individual final year projects could be part of a negotiated learning plan enabling clarification of the school's training objectives.

4. The Standing of the Qualification

One of the things that we have picked up while speaking with the students is a sense of uncertainty regarding their degree certificate which has little or nothing to do with the quality of their training, professional competencies and learning.

Certificates like the degree or foundation degree are situated in an education system where they are ranked and ordered according to academic disciplines, types and classes, and they have real consequences in terms of employment opportunities and salaries for school-leavers and graduates. In the Singapore education context, the status and value of a foundation degree is ambiguous:

> *'The guy from the first Foundation Degree class, he applied for Top Spin Aeronautics[4]. Then he said, oh our cert is totally not recognised. We go in as a diploma cert, as a diploma holder' (Xiling, learner).*

Students such as Xiling express frustration that their certification as a 'degree' and/or 'foundation degree' holder in aircraft engineering does not necessarily come with the same recognition and privileges as the other degree certificates awarded by the public universities. They express doubt about the value of the three year programme and their degree certificate especially when measured in terms of employment opportunities, salary and competitiveness versus other graduates from similar and/or competing four year programmes.

We understand the programme as fundamentally providing basic competency to students in aircraft engineering (maintenance, repair and overhaul); to fulfil mandatory training required by the aviation regulatory bodies such as CAAS, and to help students acquire the requisite aircraft engineering licences such as SAR-66 issued by the Civil Aviation Authority of Singapore (see section *2.2. Aircraft Maintenance: Certification and Licensing*). The programme provides a dual track pathway: SAR-66 licensing and/or degree academic qualification. Da Wei, the programme coordinator, highlights that students who excel in both tracks are generally well received by employers. He also pointed out that the 'Foundation Degree' concept is not practiced in Singapore and would take time for general employers to understand it, and how students too may occasionally misunderstand the idea of a Foundation Degree.

For the students, employability or competitiveness in the job market do improve with the acquisition of the requisite aircraft engineering licenses but (some) aircraft companies also conduct in-house training for their employees, and help them acquire those licenses. This is an issue of transparency for all stakeholders: the provider, the learners and employers. Clearly this issue, be it based in fact or perception, suggests a need to establish agreement on the standing of the degree amongst all stakeholders.

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[4] Top Spin Aeronautics is a pseudonym.

4.1 Mixed Intentions: Learning, Assessment and Certification

'The syllabus (in the programme) is very closely knit to the requirements of CAAS papers like the SAR-66 Aircraft Maintenance Licence exam (see section 2.2 above). The written examinations in the programme – the textbook stuff that we will memorize, are linked to the CAAS papers like Mathematics, Aerodynamics etc. It's just that the questions are different but the topics are the same. The last paper M50 is a crazy one – it is a 2 hour paper. It is a written exam with 4 essay questions from air law to human factor and maintenance practices. It's across the board so you probably have to memorize the whole book' (Da Ming, learner).

The assessment suggests to students memorisation rather than understanding but it serves summative purposes in terms of testing for essential technical knowledge and application specific to a maintenance context:

'The purpose of the essay is to allow the competent authority to determine if candidates can express themselves in a clear and concise manner in the form of a written response, in a technical report format using the technical language of the aviation industry. The essay examination also allows to assess, in part, the technical knowledge retained by the individual and with a practical application relevant to a maintenance scenario' (EASA).

From Da Ming's perspective, the CAAS examinations are as equally important as the programme's 'degree' and the WSQ certification:

'Actually companies are looking at how many CAAS papers you have. The more you have, the higher the chances of you getting into the company. So on the average we get a few CAAS papers, mainly the human factor and the air law, which are the most difficult to pass. The more papers you have the better it is. Because if you get the papers, mostly for aircraft maintenance companies, there will be a bond when you join these companies as a technician or engineer. The bond lasts between 5-8 years for some of these companies. And during the initial 2 years of the bond, you will be made to study, to pass these exams. So if we already pass these exams it means that we can get to work on the hangar faster. So, the company actually saves time and money. But it doesn't mean that if I join the company, during the first 2 years I don't have to do any more CAAS papers. But at least the companies know that we already pass some of the (essential) CAAS papers. So that's our selling point, and that's why my whole class actually 'chiong' [literally means to charge ahead] - since we are already studying might as well go all out' (Da Ming, learner).

The examinations in the degree (honours) programme are summative assessment, and these examinations are separate from the other licensing and qualification examinations set by international and national regulatory bodies. Students such as Da Ming are strategic about what they do, where they put their efforts, and how to be more competitive than the graduates from mainstream universities and other engineering programmes. Learning is instrumental to pass exams rather than for its own purpose or good. The need for certification in the industry drives them to focus on passing the exams, getting good grades that lead to a good honours degree, in order to get a good job as an aircraft engineer.

The degree programme essentially aims to provide students with the fundamental knowledge, skills and competencies in aircraft engineering to obtain further licensing certification that enhances their employability. But much seems to be left to the learners relying on their own wits to navigate the mixed learning landscape, competitive job market, and a highly segmented industry. To a certain extent, effective learning in this course is driven by the dedicated efforts of teachers who explain and demonstrate to students/learners the essence of the profession, and create learning opportunities for them.

5. Possibilities

Our observations of the WSQ module that learners undertake in their first-year indicate strong pedagogies for formative assessment. Further, the skills and knowledge students learn in this module could be further developed with elements of *sustainable assessment* (see box in p.2) and incorporated into the Final Year Project.

Assuming that resources are not a constraint, students' learning in this programme could be supported with the development of a cognitive or heuristic model for troubleshooting different systems of an aircraft. The school could also consider the use of simulators that dynamically present different problems for students to solve, and in the process construct their understanding of the various systems, tasks and equipment. Learning could also be supported by coaching as scaffolding around these problem-solving activities. Skillsets like learning how to infer problems, establish causation and recommend (possible) solutions could be developed and/or made more explicit as part of assessment.

5.1 Self-assessment

Assessment tools such as a portfolio could be used to enable students 'to be aware of their own learning needs and teachers to enable learners' development of the necessary skills to keep on learning' (Boud & Soler 2016, p.404). A student portfolio may be defined as:

> *'A compilation of academic work and other forms of educational evidence assembled for the purpose of (1) evaluating coursework quality, learning progress, and academic achievement; (2) determining whether students have met learning standards or other academic requirements for courses, grade-level promotion, and graduation; (3) helping students reflect on their academic goals and progress as learners; and (4) creating a lasting archive of academic work products, accomplishments, and other documentation' (http://edglossary.org/portfolio/).*

Artefacts such as the Final Year Project log-book, interim and final reports, and presentation provide ample opportunities to help students accept responsibility for their own learning and performance more effectively. The benefits of self-assessment are widely evangelised and need not be repeated here. But there are concrete steps to help realise these benefits:

a. Setting goals – the goals of the portfolio are tied to how the portfolio is to be used. Goals should be specified in terms of what the learning outcomes are over time. Are the learning outcomes the ability to identify problems and situate these problems in the right context? Does it include the ability to problematise issues that lead to asking the right questions, identifying methods of inquiry and proposing solutions? What are the ways to correctly represent the amount of work, effort and resources put in by the students?

b. The basis for making assessment judgments – Establishing the appropriate assessment criteria is an important step. Assessment criteria should be tied to learning outcomes such as demonstration of professional competencies like responsibility and accountability, understanding of concepts, and problem solving.

c. Student involvement – Students need to understand the purposes of the portfolio, how it will be used to evaluate their work/performance, and how it will be graded. Providing a checklist and/or a Module Guide and asking them to read it is not enough. It cannot be assumed that students understand what the criteria are in the judging of their work. Activities have to be planned for example that enable or let students '*make conscious comparisons between self-assessments and assessments by teachers, peers and other stakeholders…*' (Fastre et al. 2013, 614 in Boud & Soler 2016, p.405) so as to develop an understanding of the purposes of the assessment and how and against what it is to be assessed.

Teaching and learning practices in the engineering fields are constantly evolving in response to industry and technology developments (see for e.g. Grasso & Martinelli, 2010; Magee, et al., 2102; Wood et al., 2012). Because of the increasing complexities of engineering systems and products, academics and professionals are not only starting to experiment with new pedagogical approaches and curricula design (see for e.g. Olin College of Engineering in Massachusetts, U.S., and SUTD in Singapore), they are also beginning to wonder if the "basic" four-year Bachelor's programme is sufficient to prepare and equip students for the future of work. Advocates and experiments in engineering education towards "holistic engineering" that emphasizes *"contextualized problem formulation, the ability to lead team-centred projects, the skill to communicate across disciplines, and the desire for life-long learning of the engineering craft…*" (Grasso & Martinelli 2010, 11) suggest ongoing opportunities for formative and sustainable assessment that we have briefly highlighted here.

6. Conclusion

In this study, we have sought to examine the lab-based and practice-oriented assessment of a 3-year Bachelor degree in aircraft engineering programme. Here, we briefly describe the broader professional requirements, industry context and the nature of aircraft engineering work within which the programme is situated. We identify the broad aims of the programme to be the development of professional competency and enabling students to gain professional certification as licensed aircraft engineers. By focusing on the curricula and assessment practices of a WSQ module and Final Year Project, we examine the ways assessment and learning have been carried-out to meet the aims of the programme. We report on how the assessment and learning enable real work utility and suggest complexity, and how all these call for development of skillsets like troubleshooting and experimentation, and competencies such as professional judgment. This case-study highlights aspects (of assessment) like feedback, authenticity, holistic outcomes and transparency of purposes and assessment criteria that are critical to learning. It also shows how students demonstrated learning-to-learn capabilities in the Final Year Project that encourages exploratory and independent modes of learning. To better support these learnings, we offer suggestions as to how assessment could be developed and incorporated via sustainable assessment strategies, and instructional design like Gott's "cognitive performance model" as an example or possibility which could be adopted to enhance learning.

Appendix 1: Learners Guide

[redacted] [redacted]

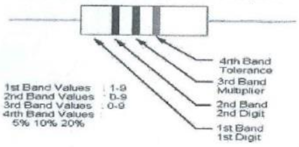
3. ELECTRICAL COMPONENTS

3.1 Resistor

The resistor is an electric component used to resist and restrict current or electron flow in the circuit. The relationship of voltage and current are in phase (together) curr ↑ = V ↑.

3.1.1 Determining the colour codes and tolerance values of a resistor

4 Band Resistor Color Code Layout



temp ↑, resists ↑

Color	1st band	2nd band	3rd band (multiplier)	4th band (tolerance)	Temp. Coefficient
Black	0	0	$\times10^0$		
Brown	1	1	$\times10^1$	±1% (F)	100 ppm
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Orange	3	3	$\times10^3$		15 ppm
Yellow	4	4	$\times10^4$		25 ppm part per mil.
Green	5	5	$\times10^5$	±0.5% (D)	

Item No.	Procedures	Trainee Sign
3	**Practice 1: Measuring resistance value of resistor with a Digital Multimeter** (DMM) (AMM) **Tasks:** a) Check the calibration date of the meter and record the next due date below: Next due date: 25-8-16 b) Connect the test leads to the meter. c) Turn the knob of the meter to 'V-Ω' for resistance measurement. d) Select to read Resistance and record the selected range below: Select resistance range: 2K range e) Determine the resistance values using the resistor colour code of a given sample resistor. Estimated value: 470 Ω f) Holding the 2 leads of the multimeter, place 1 lead on 1 end of the resistor and grip the other end of the lead with your fingers. Record the value. Measured value: 459 Ω g) Calculate measured tolerance and record the value of the resistor below: (color) Marked value : 470 Ω (DMM) Measured value : 459 Ω (diffc) Tolerance : − 2.34% meas. val − marked val. ***Note: The measured value should be within the value and tolerance from the resistor colour code.*** h) After the test, turn off the meter.	
4	**Practice 2: Measuring capacitor for leakage or open circuit with a Digital multimeter.** **Tasks:** a) Turn on the meter and select the knob of the meter to 'V-Ω' for resistance measurement.	

[redacted] [redacted]

2.2 Work Instruction and Documentation

It is a record of work instruction or defect and the work done as per instruction or rectification of the defect.

Personnel recording the work done will have to sign and "stamp" his/her authorization approval stamp against the work done.

Documentation of work is necessary for traceability and accountability.

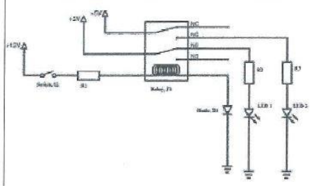
2.2.1 Planned work sheet

JOB SHEET			
Item	**Procedure**	**Action**	**Signature**
1	Check that 28Vac is available at pin 1 of connector D33889P.	**28Vac found available at pin 1 of connector D33889P per AMM xx-xx-xx**	**Signed and stamp**

2.2.2 Inspection sheet

INSPECTION SHEET			
Item	**Defect**	**Action**	**Signature**
1	Left navigation light connector found damaged	**Connector replaced and navigational light operational check found satisfactory per AMM xx-xx-xx.** **Connector batch number: AA0099**	**Signed and stamp**

Appendix 2: Assessment Record

Item No.	Process/Task:	Trainee Sign	Instructor Sign	C/NYC
	5. Present it to the assessor. 6. Turn on power and verify it with the assessor.  *Circuit to be implemented.* ***Components to be used:*** *a. Resistor, R1: ______________Ω* *Workings:* *b. Resistor, R2: ______________Ω* *Workings:*			

Item No.	Process/Task:	Trainee Sign	Instructor Sign	C/NYC
	c. Resistor, R3: ______________Ω *Workings:* *d. Diode, D1: ______________* *(PN, Ratings)* *e. LED 1: ______________* *f. LED 2: ______________* *g. Relay, F1: ______________* ______________ ______________ ______________ *(PN, Specification, Ratings)*			
3	Circuit work: (Y/N) ______________ If no, follow up action to be recorded: ______________ ______________ ______________ ______________ ______________ ______________			

Appendix 3: Students' Final Year Projects

For these students, the experience of doing the Final Year Project turned out to be a formative learning process but also a trying one. Here, we seek to identify opportunities for 'independent learning' where students can be guided to identify their learning needs and issues.

Xiling's Final Year Project to repair the school's Flight Simulator has been eventful. He reflects on his experience as fundamentally about 'troubleshooting'. Learning about and doing 'trouble-shooting' was unplanned and unguided:

> *'Actually I have no idea before I started the project. My main idea was to source for all the schematic diagrams from the manufacturer and learn how the flight simulator functions. So after quite some time of (frantic) online research, I managed to find the right company, and get all the diagrams. Then slowly study through all the notes and every single thing. Then I got the idea of what I am supposed to do. So what I needed to do actually boils down to troubleshooting the flight simulator. But how to do that (troubleshoot) and where do I begin from etc. were my main (learning) challenges.' (Xiling, learner).*

Technically speaking, troubleshooting is not a generic process of 'problem-solving'. Rather, it is a methodical systems-based approach towards problems in machines, engines and/or physical structures, the interactions within the systems and sub-systems, and the relationships between human and non-human interfaces (http://whatis.techtarget.com/definition/troubleshooting). Xiling has only begun to *intuit* the logic and methods of troubleshooting on his own. He understands troubleshooting primarily as a task or activity rather than as a framework of understanding, a conceptual device or heuristic for/of problem-solving.

Irfan's Final Year Project is the development of a visual teaching aid for an aerodynamics module. His project comprises mainly the design and construction of a (scale model) motorised variable pitch propeller rig that produces for example thrust, RPM (Revolutions Per Minute), and so on, which could be recorded and measured. It involves a continuous and iterative process of testing, data and information gathering, and constructing. Irfan conceptualizes his teaching-aid project as follows:

> *'The notes (from the aerodynamics module) were quite thorough: they were quite detailed and there were nice schematics and pictures inside – so that covered 'abstract conceptualisation'. And there was 'reflective observation' (these terms were 'Googled') when the lecturers went through the module at that time, like two years ago. They showed videos and stuff like that, so yes, that's like where we learned from. However, in my personal opinion, I feel that they lack 'active experimentation' and 'concept experience'. So the school covered the first two points very well but not the other two which are what I'm trying to cover for the Final Year Project. So I try to make it a more comprehensive experience for the school. I mean, that was like my idea for my Final Year Project. So that's the goal' (Irfan, learner).*

Based on accounts from Xiling and Irfran, the Final Year Project requires exploring, experimenting and decision-making. It takes perseverance, the ability to identify, name and solve problems. It is meant to *provide a broader scope of education to enhance students' understanding of the aviation world and be independent in their approach to daily work* which would require them to 'learn how to learn' as they progress along their future careers.

Projects such as Irfan's and Xiling's are quite sophisticated and require a lot from them; these projects call for (new) ways of thinking about and doing things like 'prototyping'. For Xiling, the essential concept and task of 'troubleshooting' could be incorporated into the appropriate modules with its own set of learning outcomes to help students see patterns, identify and situate problems more methodically. He understands the value of what he has learned from the Final Year Project, and he is able to intuit where these learnings are situated within the real world of work and the industry:

> *I think my project is oriented more towards flight simulators, which all the big companies are using to train their pilots. So, I do have a better knowledge of how the flight simulator works! And, actually how the airplane flies, all the flight controls in the cockpit, I now know all these. And, as for the technical part, I have become more familiar with how to troubleshoot, and ways to troubleshoot a system. (Xiling, Learner).*

Perhaps, concepts such as 'prototyping' and 'troubleshooting' could have been made more explicit, by incorporating them into the curricula and learning strategies in order to enrich and enable 'independent learning' as an experience and learning outcome of the Final Year Project.

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