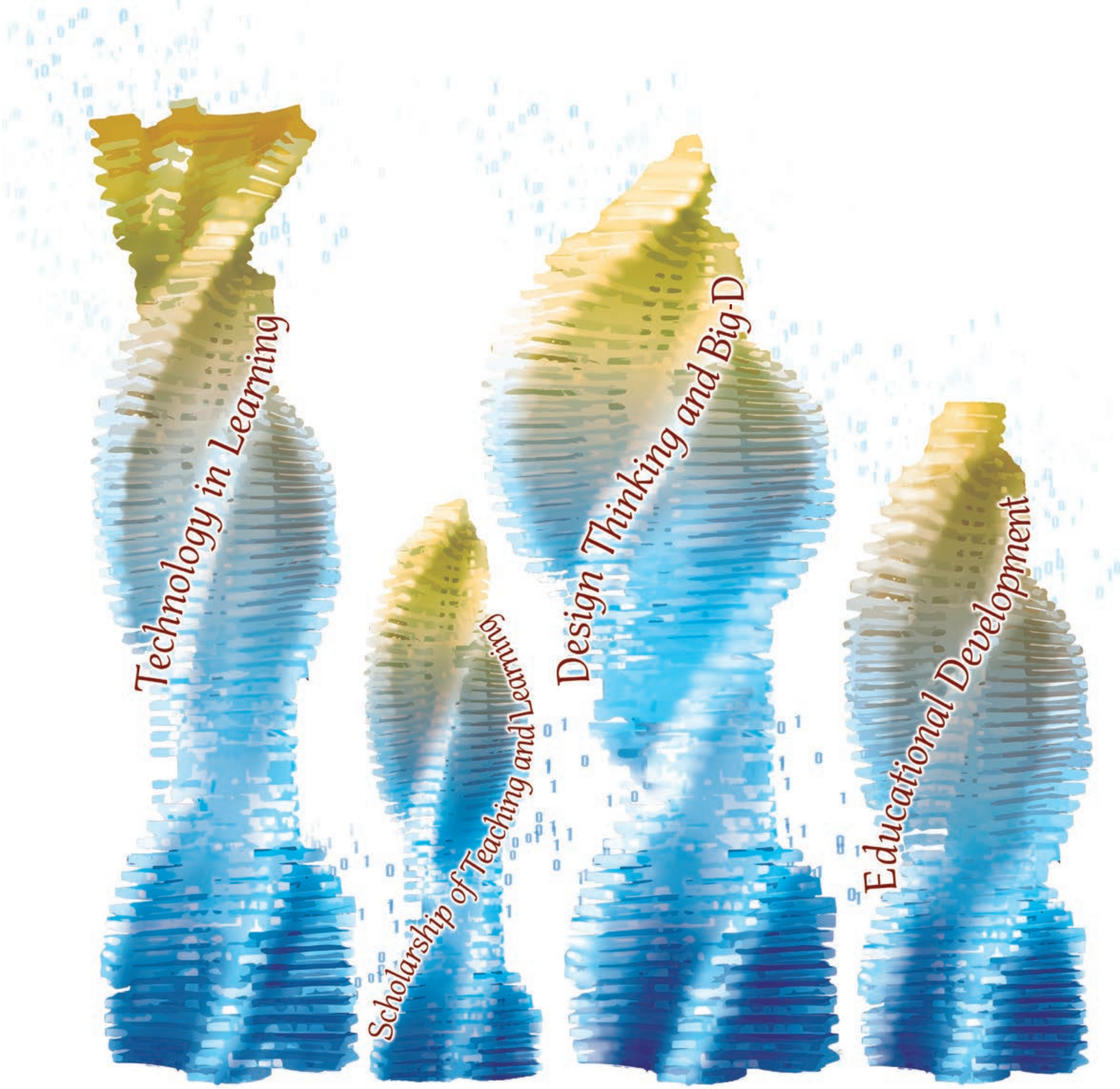
EDITION /003

EduSCAPES

AN SUTD PEDAGOGY NEWSLETTER



SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

10 YEARS IGNITING INNOVATION BY DESIGN

LEARNING SCIENCES LAB
OFFICE OF UNDERGRADUATE STUDIES

AIMS

This newsletter aims to promote and celebrate teaching excellence and experience at SUTD, by taking a reflective, evidence-based empirical approach into teaching and learning practices at SUTD and beyond, to identify innovative and effective pedagogies for SUTD. We also hope that the newsletter will serve as a platform for sharing pedagogical resources on technology and library tools.

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As a central and university lab on teaching and learning, Learning Sciences Lab (LSL) from the Office of Undergraduate Studies (UGS) plays a vital role in shaping and coordinating this newsletter, by leading and working with various stakeholders from SUTD.

LSL, established at SUTD in July 2016, aims to support instructors and learners in engaged teaching and learning. LSL offers various programs and services on teaching and learning to faculty members, graduate teaching assistants and learners. LSL aims to build communities of practices in teaching and learning at SUTD - within and in collaboration with other universities. LSL is led by Nachamma Sockalingam.

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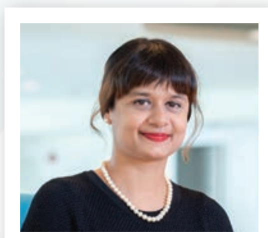

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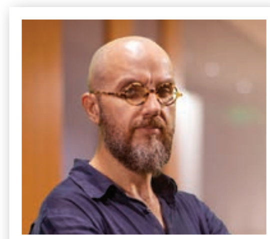
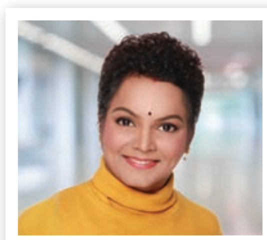
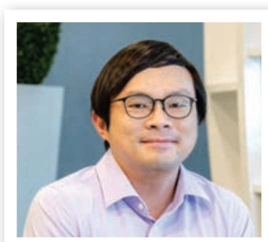


Paolo Di Leo



Nachamma Sockalingam



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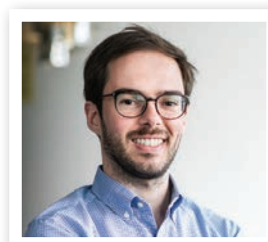

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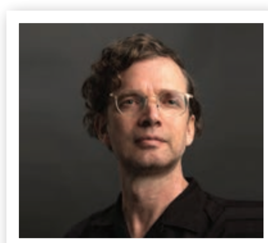

Oliver Heckmann

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GUIDELINES FOR SUBMISSION

WE ACCEPT A VARIETY OF ARTICLES IN THE FORM OF:

Current Issues
This could be a write-up of the latest happenings in the education industry on topics such as learning analytics and project-based learning

Reflections
This would be opinion and reflective pieces that involve sharing of perspectives and experiences

Research Articles
Research articles are empirical, evidence-based write-ups of action research/inquiry into teaching and learning

Different Perspectives
This would be interviews with various stakeholders

Book Reviews
Review of books on pedagogical topics

Teaching Resources
Write-ups from various offices in SUTD/external stakeholders on teaching resources

YOUR ARTICLE SHOULD

- ✓ Meet the aims and scope of the newsletter
- ✓ Be well-written and easy to follow, without unnecessary technical jargons
- ✓ Be original – not reprinted anywhere else
- ✓ Go beyond being descriptive – should attempt to take a more empirical, reflective approach
- ✓ Highlight the impact and significance of the findings

Please send your articles to lsl@sutd.edu.sg

EDITOR'S NOTE

It is our great pleasure to bring you the third issue of **EduSCAPES: the pedagogy newsletter from SUTD**, which presents the **diverse educational landscapes** at SUTD in one place, providing a **refreshing escapade** from the humdrums and daily routines of academic life.

EduSCAPES is called a newsletter as it brings both news and letters or reflections from diverse members of the SUTD colleagues, in their own voices. We hope to include articles from the community rather than writing on behalf for the community. This is a newsletter for the community by the community. We thank all who have contributed to this edition.

It is a great pleasure to see the growth of the newsletter over the years from 40 pages to 50, and now to 70 pages, bringing articles on wider ranging topics, from various sections of SUTD, showcasing the enthusiastic engagement in pedagogical projects, innovations and publications.

This year's newsletter cover portrays pillars of double helical structures symbolizing the genetic code underpinning SUTD's education- Design and Technology. The pillars are reflective of our SUTD pillars and clusters.

The double helix underpinning SUTD's excellence in teaching are Scholarship of Teaching and Learning and Educational Development. Scholarship of Teaching and Learning (SOTL) is essentially about taking a scholarly approach to teaching and learning, as opposed to simply intuitive teaching based on good common sense and valuable experiences. In addition, SOTL is based on evidence-based and reflective teaching practices that is shared with the public. What is unique about SOTL at SUTD is that it is inclusive and involves the various support units and staff members in addition to faculty members. This is evident in our newsletter contributions.

In general, SOTL is thought to improve teaching and learning and contribute to the educational development of the institution. One may wonder if there is any real impact of SOTL practices. Let us consider this newsletter as an example. SUTD's Pedagogy newsletter is one of our various platforms of public sharing of the SOTL works at SUTD.

1. Over the last three years, we observe that there is an increased number of contributions and a wider number of faculty and staff members contributing to the newsletter. This can suggest that more are engaged in such evidence-based, reflective teaching practices.

2. Several of these studies demonstrate there is a deeper understanding of teaching and learning practices in the classroom. What works and what does not.

3. A check with the individual faculty members involved in these studies would reveal confident responses that becoming a reflective and scholarly teacher has helped them improve in their teaching practices.

4. Often there is a significant improvement in learning outcomes and learning experiences in each of these studies. This includes an increased student- teacher interaction. The improved student learning outcomes and experiences, documented in these studies, support that.

5. As a result of the public sharing, more at SUTD become aware and interested in pedagogical projects and start innovating and enhancing their teaching.

6. Overall, there is an increased teacher engagement, and evidences seem to suggest improved learning experiences and outcomes. While SUTD's pedagogy is predicted to be well-suited for preparing future-ready learners, these SOTL reports and reflections presented here provide assurance that this prediction is supported by empirical evidences, and that the SUTD community as a whole is committed and continually engaged to providing a great learning experience for our SUTD students.

We hope that this newsletter also inspires great teaching practices beyond SUTD in our pre-university schools and that it builds more collaborations and partnerships. This should also assure potential incoming students and parents on the quality of education at SUTD. As we know, teaching takes up much time and care. Innovating teaching practices means that this involves taking additional time to learn and design new teaching activities and assessments, and this is done with the deliberate intent to improve teaching and learning. Taking a SOTL approach means going even further than this because SOTL involves designing a proper study protocol, applying for institutional review board approval to conduct such studies ethically, designing and implementing relevant and suitable interventions, collecting valid and reliable data, analyzing, and writing up a report or publicly sharing. So, it is important to recognize the extra miles that SUTD faculty and staff members go to and the passion they have for designing a better education for our future leaders and innovators. Our students are assured of rich learning experiences from not just the faculty members, but the institution as a whole.

Now, let us see what this newsletter covers. We have five sections this time; starting with Different Perspectives, Awards and Grants, An Overview of Education and Development at SUTD; Pedagogical Reflections and Teaching Resources. These contributions focus on the two underpinning codes of SUTD's education; Design and Technology.

In Different Perspectives, we bring you a dialogue between two professors on an interdisciplinary approach to Artificial Intelligence and Philosophy and how SUTD enables this interdisciplinarity in its course work. We also have a reflection from a Science and Maths Lecturer on inspiring learning of these subjects. Next, we bring you some our proud moments of educational awards and achievements at SUTD in the last one year.

Following that, we bring you two articles on Education and Development at SUTD, and these provide a helicopter view of SUTD's education- one on the concept of Big-D at SUTD and the other on benchmarking educational development centres in Singapore. Next, we bring a rich collection of studies and reflections on design-centric and technology-enabled teaching and learning at SUTD. The design-centric reports include case-based learning, experiential learning, authentic learning in partnership with industrial partners, and design thinking and innovation. The technology-enabled learning reports include gamified learning, learning using virtual reality, 3D printing, and online assessments.

Finally, we bring you various articles of teaching resources that support teaching and learning in terms of team collaboration, working safely, opportunities for life-long learning at SUTD, and the support from academic facilities and Library at SUTD.

We hope that you find the newsletter informative, enjoyable and inspiring. This would be an annual newsletter and we invite all interested in SUTD's pedagogy (including students) to contribute to subsequent issues. Please see the guidelines for submission. We look forward to your contributions. Share with us and others your insights, reflections, findings on teaching and learning by emailing us at lsl@sutd.edu.sg.

NACHAMMA SOCKALINGAM
PROGRAM DIRECTOR, LEARNING SCIENCES LAB
NOVEMBER 2019

DIFFERENT PERSPECTIVES

COMPREHENDING ARTIFICIAL INTELLIGENCE AND OURSELVES THROUGH PHILOSOPHY

MS. CHEW YUNQING, ARCHITECTURE AND SUSTAINABLE DESIGN (ASD)

Prof Costas Courcoubetis from ESD and Lecturer Paolo Di Leo from HASS join hands to cook up an exciting new course, **Being in the World: Homer, Heidegger and A.I.**, that brings forward new pedagogical possibilities.

They sit down together to discuss the urgent relevance of such a course for engineering students to gain ownership over how they think about the sensationally termed bracket of technologies we call Artificial Intelligence (AI). They firmly believe that when students are freed from the mental constraints of the hidden assumptions riddling common discourse on AI, students can potentially harness these technologies to better effect, or even create new ones. They also share on the pedagogy design considerations they had, as well as other key insights.

Why offer this course on A.I. & Philosophy?

Paolo: It is a course which combines both the philosophical approach and a reflection on these new technologies that are coming up, above all of the discussion regarding AI. It aims to provide students with a better understanding of the epistemological assumptions behind these tech advancements that go under the label of AI, of examining what is it that we mean when we say 'intelligence', and once we have reached a better understanding of the phenomenon of intelligence, wonder whether the very label 'intelligence' is conducive to talk about these technological advancements that we witness in this period.

Costas: The goal is not just to talk about AI, but being a scientist myself and an engineer, I feel trapped in today's world of technology, and in ascribing worth to a single meaning. I believe that students will benefit a lot by understanding how people have been searching for the truth since we first established the disciplines of Science and Philosophy, and that will make us understand what we are doing today.

Philosophy has always been a quest for certainty, and finding a way to give the right answer to what is Truth and how we can understand things. This evolved from the ancient Greeks to today, and modern Science is based on that. The goal of this class is not to pick one of the different philosophical approaches that people have proposed over the centuries on what is truth and how we can find it, but understanding the process of doing it, to understand that today we are still in this kind of process but we have not found truth, or even worse, we don't want to be completely immersed in the one specific way of understanding things. I will be very happy if our students feel more free to develop their own thinking and understanding, and not to feel trapped in certain interpretations that every university, every school, and every society today is steeped in, and experience the freedom that accompanies the insight that there is more than one way to understand things.

How do you believe that this course will directly benefit SUTD students?

Costas: Typically, you have pure HASS courses and pure engineering content, but we would like to do something that bridges the two. That does not mean that you teach both, but you give students the mental tools that are useful for engineers to better understand what is happening around them.

Most of us who are scientists and engineers are trapped in this technological way of thinking, we stop looking at things with a fresh eye, to really understand it. We lose this freshness of thinking and hence the ability to respond to a situation by understanding it in its peculiarity. We impose on them a lot of structures and assumptions about what they mean, why they are important and how things are. We think that those things are the Truth and take many things for granted. Everything becomes similar, one-dimensional, KPIs, everything becomes formulaic, as if it were the spreadsheet that we input everything into. The moment that you accept that there is this spreadsheet, then you lose all the complexity of the universe because everything becomes the problem of fitting into this spreadsheet.

You have to understand that spreadsheets are useful when you want to use them for some reason, but they are not the truth. Spreadsheets are a way to handle things, to minimise complexity, but they are not the way to understand what something is. Somehow I have a feeling we are all trapped in this state where the efficiency justifies it. Students must understand that they can use spreadsheets as much as they want because they are smart and efficient and want to make things work better but they have to understand there are situations in life or in Science where they have to make a decision and get out of this frame of mind and really see it as they are.

Paolo: Some of our students are entering the industry as employees in some kind of enterprise, and some of them will also get roles or responsibilities in which they will have to make important decisions or they will be faced with the fact that they will have to come up with new ideas and ways of using existing technology or making an existing technology take a certain turn. If they are totally trapped in a frame whereby they assume human intelligence is just calculation, what kind of decisions are they going to make regarding this technology? This question is particularly pressing, because that can have a huge impact on our lives on a daily basis. Maybe they will not be able to make a decision that is based on a holistic view. In that sense, this course will be beneficial to our students in that some of them are going to be leaders in innovation. Even those who end up working for an enterprise will come out of the experience with a more solid understanding of how things are and the power to imagine what they can be.

> "The moment that you accept that there is this spreadsheet, then you lose all the complexity of the universe because everything becomes the problem of fitting into this spreadsheet."

For students to realise that there are other interpretations available, do you think the university should first show them the boundaries?

Costas: I think that is a very important question that the course perhaps tries to achieve, but I don't think there is a cookbook with rules on how to do that.

Every university today is immersed in a specific way of thinking, which comes from Cartesianism and so forth. The first step is to educate the students about exactly that - realising the limits of the way in which we think now, and realise there is this foundation of the Western thinking in which we are immersed, like a fish in water. We don't even question it because it seems natural, but we have to be able to get out of it.

Paolo: For example, there is a lot of talk now, in England and America, about the ethical risks of AI, saying that all these machines will take over what now is our domain and we will be pushed to the margins. These, in a way, are legitimate concerns. But what this discourse skips is the fact that these machines will be put in the conditions to be able to push us to the margins only because we have decided to do so. On the other hand, the real risk consists in the fact that we human beings start understanding ourselves and our intelligence only as calculative machines, which is already happening. So the risk of AI is not something to come in the future, it is something that is already among us, even before the machines have really developed a super powerful calculative ability. We already understand ourselves as calculators, hence we limit ourselves within that frame. The important thing about understanding the foundations, from which this comes from, implies the possibility, as Costas was saying, not to remain trapped in this way of understanding ourselves in the world. That I think is a very important task a university like SUTD has to fulfill if it wants to really be true to its mission of combining the kind of knowledge that comes from the Humanities, Philosophy in particular, and the technical knowledge that comes from all the other disciplines such as Engineering.

Costas: Somehow we are creating a wrong understanding of ourselves, which can really limit our creativity and our ability to do things as humans. That is the big scare of technology, that you start seeing yourself as a technological tool. You should not let yourself be dragged into this kind of situation.

Before we can begin to talk about what Intelligence and Artificial intelligence are, it doesn't seem to me that we have an adequate understanding of what Science and Technology entails. How should the course incorporate that aspect?

Paolo: The challenge is that SUTD, like many other institutions that are created in the past 10 or 20 years is not a university in the classical sense of the term, in that you don't have a department of philosophy proper where people come and study Philosophy in all its branches and aspects, nor do you have a department of physics where people come and do abstract research in Physics. SUTD is more of a combined kind of higher education experience whereby we are supposed to prepare our students for the job market, and give them some kind of core understanding that grants them a holistic view of each problem they are going to be facing.

Given that this is the situation of SUTD and of many other such universities in the world these days, you cannot expect to first have a course on the foundation of science through Philosophy and Ethics and so on. What you have to do is to be able to offer a course that presents the material to the students in a way that they can immediately grasp, problematizes this material, and refers them to books' chapters and academic articles that give them more depth into problems that nevertheless are discussed in newspapers and conferences. We start from what the students are familiar with, making them see what is problematic in the general approach and its assumptions.

> "We start from what the students are familiar with, making them see what is problematic in the general approach and its assumptions."

Costas: Instead of having a formal course on the scientific thinking, which by itself can require prerequisites, this class will spend at least 30 percent of it to make us understand how this scientific method has developed across centuries and the philosophical thinking that led Science, because Science used to be part of Philosophy. Everything, like Mathematics, Physics, and Astronomy, used to be in the domain of Philosophy. That is why the PhDs are Doctors of Philosophy. So we do that not by a formal way, but start from more practical issues.

Paolo: To give an example, weeks ago on the New York Times, an article came out where a philosopher of consciousness was interviewed. He teaches at an American university and is one of the experts of the AI discourse. I'm sure that many students at SUTD and elsewhere have read this article agreeing with him, taking for granted that what he says is indisputable, when in fact all that he says, which then influences the discourse on AI, is built on a series of assumptions, the roots of which you can find in Descartes and Plato. These assumptions are not pacific; they are a matter of contestation. Are we sure, for example, the mind can be thought of as a little man that lives inside the body? Because ultimately that's the understanding based on which we talk about AI: a mind that is put inside some kind of instrumental envelope. Are things like that? 250 years of philosophical tradition have disproved this approach and there are very good arguments there.

Costas: There could be other technological advancements, like neural networks, that are much closer to the way intelligence is manifested, because it's not like a symbolic manipulation system, which moves away from the computer as getting the outside information, making its symbols, and processing it to give you an output. A neural network is in the world and always change and adapt to it. There are many models today, some of them are more interesting. In this course we would like to go through some of those models and understand the basic differences and what are the more viable that are closer to what we understand as human intelligence.

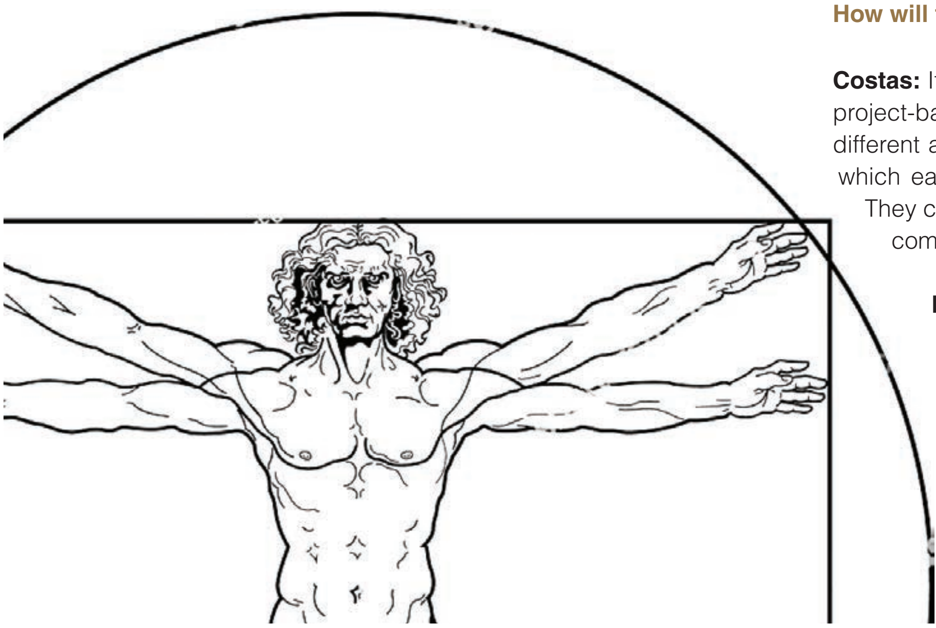
How would you differentiate between Science and Technology?

Costas: In simple terms, technology is something you build to use and science is a way of thinking so that eventually you can have technology. Without science you cannot have good technology. Science is like a broader world of knowledge; part of that gets translated into technology but some may not - not all of mathematics, or physics, or biology. Usually technology is something practical and specific, but it can also be a way of thinking, like this kind of enframing where you accept that everything should be input into a spreadsheet. The moment we accept that any problem we have, we should be able to express it in symbols and spreadsheets… in other words, the moment you assume that everything that is answerable should be answerable by a spreadsheet, that's a type of technological thinking.

Paolo: In my mind, the one who best characterises the relationship between Technology and the Sciences has been Heiddeger. He subsumes them both under the word 'Techne'. 'Techne' is the way to organise your thoughts in terms of understanding everything under the principle of cause and effect. So thought gets understood as a tool that must produce certain effects. These effects might be theoretical or practical. But at that point both the theoretical - pure science - and practical - technology - are already subsumed under a certain way to understand what thinking is, namely, thinking understood under the label of 'techne' that is a way to produce effects, hence some kind of production. This starts already with Plato, Aristotle, and then develops during the course of Western philosophy when Descartes said "Cogito Ergo Sum", the 'Sum' is the result of the 'Cogito', hence the Cogito is some kind of productivity.

How would you organise this course from a pedagogical point of view?

Paolo: The best way is to start from something that students can immediately grasp, so for example an article on the New York Times, like the one I referred to, or a TED talk. Starting from these things, having the students read or listen to them, comment on them, this will allow them to problematize these things, showing the students the assumptions that govern the general argument and the conclusions in the article or the speech. In doing this, as the discussion evolves, we will refer students to deeper material, books, academic articles. The hope is that they can participate because we start from something that they can immediately relate to.



Costas: There is a lot of good material in the world, and there are many smart people who have been touching on these issues but not in a systematic way that we can put in a course. We can put this material all together so students have access to it. When they go home they have time to read. In this way these questions will be easier to understand than if faced directly through philosophical articles, because philosophy articles are notoriously difficult to read. We would like to talk about all those important topics in a simpler way, giving them the resources that they can have access to so they can spend 3 or 4 hours to go through them.

Paolo: When you read an article on AI, like the article I was referring to, there are parts that are extremely technical, that I myself need to ask someone who knows technically about these things. There are in these articles also these philosophical assumptions that usually go unnoticed. Why? Because as Costas was saying before, we swim in Cartesianism, in Platonism, as if it were natural, because we come from 2500 years in which we have learnt to see things through the Platonic view, and don't see these assumptions anymore. The job of the philosopher then is that of making people notice "look, this is a philosophical assumption, and this is another." What you want to do is based on a philosophical assumption of how things work. If that assumption is wrong, or is limited, or is too partial, you are going to limit yourself and frame yourself in that assumption, and lose the ability, as Costas was saying, to do things because you keep yourself to a protocol basically.

Costas: You see technology today forces us to get into this protocol. If we accept that, every question we ask is defined within this framework that is set upon us from the outside. If you let yourself be enframed like this you have a complete system. But the moment you reject the framework, you are free to understand things differently.

How will the class be graded?

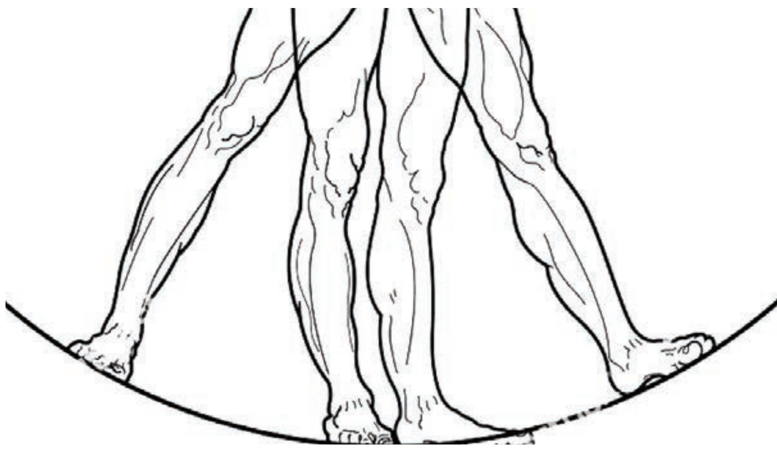
Costas: If you participate you will get a better grade. It will be project-based, of finding problems and attacking them from different angles. Ask students to do group-based projects, in which each student is given a problem taken from real life. They can be given an article to identify its assumptions and comment on their own positions.

Paolo: Classical grading in a course like this would be ineffective. What you are going to grade is the ability to ensure they understand the problems but the best way for them to show this ability is in a presentation.

Costas: To ensure students have grasped the fundamentals, every week we give them 10 questions that summarise all the main points of the course then we give them the answers. The questions are multiple choice, not to ask you to write the story of your life. At the end you present the project.

Closing remarks...

Costas: SUTD is proud to claim that it has a strong Social Sciences foundation. It is a challenge for people in the social sciences to influence people who are in engineering. We try to conduct this course in a way that is going to be easier for engineers to take. It should be like a first contact for them with no prerequisites. People that come into this class, should come with an open mind.



ABOUT THE AUTHOR

Yunqing is currently a second year student enrolled in ASD and had previously attended the World Texts course under Professor Di Leo. She is interested in exploring and learning beyond her academic courses at SUTD.

WHY ARE WE LEARNING THIS?

REFLECTIONS ON SCIENCE AND MATHEMATICS EDUCATION FOR FUTURE-READY ENGINEERS AND ARCHITECTS

DR. TAN DA YANG, SCIENCE AND MATH (SCI)

A spherical cow, by Ingrid Kallick (http://www.ikallick.com)[1]

The one question that I received quite a bit when teaching the physics and mathematics classes the past year was "Why are we learning this?" Given the unique curriculum at SUTD that allows for a broad-based science education for all the Freshmore (undergraduate year 1) students, I feel compelled to seek the answers for this. I decided to take some time to reflect and consider the significance of a science education within an architecture and engineering university, especially how ingrained this has been in the curriculum. I must, however, state that all the views articulated in this reflection are largely constrained by my anecdotal experiences and can be (and should be) open to discussion.

Science and mathematics education provides the exposure for students to develop the relevant scientific, inductive and deductive reasoning, the ability to solve problems by forming hypothesis, to see beyond the black box and to challenge the assumptions within each formalism, at least in my view. More importantly, science and mathematics education, by its curiosity driven nature, encourage students to question why and to seek solutions to that question, a skill that is important as future innovators and technically-grounded individuals. In the classical mechanics' class in Physics I, students are constantly challenged to understand the assumptions, such as why linear momentums are (approximately) conserved for short interaction times between particles, and how come only the motion of the centre-of-mass of the object (hence treating it as a point object) is considered in many situations, while not having to worry about the geometry of the object until the need actually arises. Similarly, in the Advanced Mathematics I course, students were similarly challenged to understand how exponential functions and Euler's number ought to be different, and yet they are ultimately just two sides of the same coin.

One of my favourite examples would be the physicist's joke that "assume a cow is spherical". As ridiculous as it may sound, by making this crude assumption one could already make a first order approximation on the volume of the cow, which is not too bad for a first try. In fact, for many of the computational simulation tools, it is not difficult to find some form of coarse-graining assumptions in-built since there is only so much computation resource one can harness typically. It is hence imperative to understand how and where the various assumptions come into play, and the ability to appreciate so is in-built within the science and mathematics curriculum.

Hence, such forms of exposure could not have been possible if one only considers the pragmatic and utility-based use of Physics and Mathematics. Based on the metric of utility alone, one only needs to consider both physics and mathematics principles to be black boxes and the ability to use it would suffice. Yet, one can argue that necessary rigour is needed for the grooming of future creators and innovators who can appreciate, challenge, and understand the underlying assumptions in between any new ideas. This would certainly go beyond just being able to use the concepts, but thorough consideration of what underpins these concepts and calculations.

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[1] The image was created by Ingrid Kallick for the program cover of the 1996 annual meeting of the American Astronomical Association. An earlier version was created for the National Center for Supercomputing Applications. The artist gave permission for use to the University of Wisconsin Department of Astronomy. The STScI subsequently used the image.http://www.ikallick.com, Public Domain, https://commons.wikimedia.org/w/index.php?curid=3498985

Beyond personal development, many fundamental concepts that are rooted within fundamental science have found its relevance in other disciplines, and this sets the basis for a symbiosis between disciplines and generation of new innovations and ideas. As an illustration, self-organisation, a concept originally used to describe the phase transitions in physical systems (e.g. changing of states between solid, liquid and gases), has found renewed applications not only in understanding the coordinated movements of flock of birds (i.e. in biology, another fundamental science), but more unexpectedly, in the study of human society as a whole. Beyond physical systems, the concept of self-organisation has found itself relevant in explaining the traffic behaviour, for instance the existence of traffic jams that seems to appear for no apparent reason (known as phantom traffic jams); to explain how social contracts within a society affects the human behaviour and even the spatial environment, for example how the bottom-up cooperative management of the rice terraces between farmers in Bali give rise to the picturesque spatial patterns of the rice terraces. The key take-away here is that inspirations for new insights and innovations are often embedded within the world around us. More will be elaborated in the paragraphs below:

In the learning workshop held earlier this year for the Freshmore students, an excellent example of how fundamental sciences served as an inspiration in the design of the Eastgate Centre in Zimbabwe was discussed. The unique design for thermal control within the building was inspired from nature, by looking at how termites' nests were formed naturally. Such inspirations, coupled with the practical physical thermo-principles, led to the passive cooling design that helped to create a sustainable building with significantly reduced the carbon footprint through minimising the need for air-conditioning.

Another example can be seen in the trending area of neural networks and artificial intelligence. The first artificial neural network could be attributed to Frank Rosenblatt, an American psychologist who was known for Perceptron, which was inspired by biological principles for use in image recognition in the 1950s. One could easily argue that the basic model for artificial neural network mimics (at least to a crude approximation) neurons and synapses in an actual biological system. In fact, such examples are everywhere: from the kingfisher's beak design to break air and the mimicking of the owls' feathers for silent movement through the air in Shinkansen, to observing the semi-elastic beaks of woodpeckers as nature's shock absorbers. Such inspirations are everywhere, yet it is only with sufficient exposure and awareness that one can uncover all these hidden gems. One can further take the philosophical view that the biological nature, having evolved at least over billions of years, and having undergone many rounds of iterations and evolutions, should have many impressive designs that we can mimic.

Even from a pragmatic standpoint, the future of jobs is constantly changing. A career path that may seem trendy today may not be relevant tomorrow. The World Economic Forum released a report on the future of jobs in 2018 and one could easily observe that many of the stable and new job roles in the future involved either the softer aspect of human interactions or technical roles that requires new knowledge. The latter was emphasised in the trending skills demand that included items such as "analytical thinking and innovation", "active learning and learning strategies", "creativity, originality and initiative" and "critical thinking and analysis". These new roles essentially demanded the new job seekers to be able to adapt and innovate. In the fast changing world where one must be able to adapt to the ever-changing new knowledge, one can argue that fundamental science and mathematics, on the other hand, are largely invariant, and the ability to understand the principles behind how our world works, will set one apart from the others by being able to come up with technically-grounded solutions and innovations that are backed by a solid foundation of science and mathematics. This is true not only for the acquisition of the knowledge and information itself, but even more importantly, the underlying reasoning behind the knowledge and information.

Lastly, given the ever increasing amount of information one has to process with the onset of the digital age, the systematic study of fundamental science (i.e. the process of acquiring new knowledge from nature) offers students the skills, discipline and reasoning of acquiring new knowledge for themselves. In the backdrop of ever increasing overload of information, this has become a crucial life skill, without which one cannot survive the new digital savannah.

The futuristic world not only requires citizens who can work, but also citizens with the capacity to have in-depth understanding of new knowledge. Scientists and mathematicians, being always at the frontier of new knowledge, will be able to impart these skillsets to the next generation of creators and innovators, allowing them to stand on our shoulders and see much further. The question is then this: how far do we want our next generation to be able to see?

Acknowledgements:
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AWARDS AND GRANTS

INTERNATIONAL AWARDS

ISSOTL FELLOWSHIP AWARDS 2019

Nachamma Sockalingam (LSL) was conferred the ISSOTL Fellowship Award.

The International Society for the Scholarship of Teaching and Learning (ISSOTL) Fellowship recognizes educational leadership in terms of community engagement, global citizenship, and collaboration in building capacities for new ways of thinking, doing, learning and holistic, meaningful and intentional approaches to higher education. The inaugural ISSOTL 2019 fellowship recognizes 9 fellows globally, with 1 from Singapore (SUTD).

Best Poster Award for Asian Materials Education Symposium 2019

Grace Dixon (HASS) and Tan Mei Chee (EPD) won the best poster award 2018 for their educational project on "Materials Driven Innovations: Two Case Study Perspectives" by Materials Research Society, Singapore.

Excellence in Design Science Paper Award

Ryan Arlitt (Technical University of Denmark), Sumbul Khan (IDC-SUTD) & Lucienne Blessing (EPD)

The paper presented a study on developing a scalable computational approach for design thinking assessment.

SUTD TEACHING EXCELLENCE AWARDS 2018

Senior Lecturer Dawn Koh (SCI)

"Constantly upgrading my pedagogy for my classes and assessing their effectiveness to enhance student learning experience.

Once you put 100% of your heart and soul into nurturing your students, you would find yourself excelling in your work and winning awards would come naturally. Even if you do not receive the award, I am sure the inner joy that you experience through impacting a young person's life would be just as rewarding. Keep on doing the amazing work!"

Senior Lecturer Oka Kurniawan (ISTD)

"Students told me they appreciate my effort in teaching them. I have also been involved in leading and revising Digital World course for freshmore and some other pillar courses. Moreover, I had the opportunity to do some interesting pedagogy innovation funded by Education department.

For us educators, we all know that our greatest award is when we see our students able to learn on their own without us and grow to be the best person they are meant to be. Be ready for unexpected little awards. It is when we meet our previous students in unexpected places and unexpected time, and they call you out and say in many hidden ways … Thank You!"

PEDAGOGY INNOVATION GRANT RECIPIENTS 2018 & 2019

Pedagogy innovation is an important aspect of education. The Office of Undergraduate Studies funds Pedagogy Innovation projects to promote innovations in teaching and Scholarship of Teaching and Learning. Faculty members are invited by the Office of Undergraduate Studies to submit project proposals bi-annually through email announcements. Submitted proposals undergo criterion-based selection by a review team. The theme for the Pedagogical Innovation projects vary from year to year.

Following are successful proposals from 2018 and 2019, under the theme of Digital Learning. Office of Undergraduate Studies would like to encourage all faculty members to innovate teaching and engage in a scholarly teaching, evidence-based evaluation and inquiry into teaching and learning, and participate in the fund application.

Interested faculty members can approach us at learning sciences lab for consultations and collaborations on educational research projects.

2018

Investigating The Effectiveness of Gamified Laboratory Simulations At Enhancing Biology Education
Bina Rai (SCI), Leo Chen Huei (SCI) and Yajuan (Julia) Zhu (SCI)

AR/VR For Robot Simulation In Teaching Introductory Programming
Oka Kurniawan (ISTD) and Subhajit Datta (ISTD)

Digitizing and Visualizing Flowers and Aromatics in Classical Chinese Poetry
Zhenxing Zhao (HASS) and Lim Sun Sun (HASS)

Adaptive Notes
Massimiliano Colla (SCI)

Revision App
Massimiliano Colla (SCI)

Better Learning by Collaborative Design Cloud
Sam Conrad Joyce (ASD)

Smart Prediction of Students' Programming Performance for Early Intervention
Norman Lee (ISTD) and Oka Kurniawan (ISTD)

2019

Thermodynamics and Physics Kits – Innovation Through Standardization Of Basic Components
Massimiliano Colla (SCI)

Improving Students' Perception towards Physics through Gamification and Online Learning Platform
Tan Da Yang (SCI) and Cheah Chin Wei (EPD)

Mixed Reality Application to Teach Introductory Programming
Oka Kurniawan (ISTD), Norman Lee (ISTD), and Nachamma Sockalingam (LSL)

Learning Outside the Classroom—A Winning Combination to Solve Unmet Healthcare Needs?
Dawn Koh (EPD)

Using Machine Learning to Understand Student's Learning in Multidisciplinary Courses
Kwan Wei Lek (EPD) and Maggie Pee (SCI)

OVERVIEW

BIG-D AT SUTD

DR. NACHAMMA SOCKALINGAM, LEARNING SCIENCES LAB (LSL), OFFICE OF UNDERGRADUATE STUDIES (UGS) AND PROF. PEY KIN LEONG, OFFICE OF UNDERGRADUATE STUDIES (UGS) & SUTD ACADEMY

Singapore University of Technology and Design (SUTD) celebrates its 10th year of establishment this year. This marks a special milestone for us, and it is probably a good time for us to pause and reflect on our progress in advancing knowledge and nurturing technically grounded leaders and innovators to serve societal needs.

SUTD is the fourth public university in Singapore and is relatively younger and different compared to the other universities in Singapore. SUTD is unique in many ways. This can be in terms of various aspects such as size, culture, approach and pedagogy. Obviously, no two universities are alike in general. Of the many differences, the Big-D framework is possibly one of the key differentiating factors to define SUTD.

As our name suggests, Design and Technology are the double helical strands of SUTD's DNA. The term "Design" can be interpreted variedly. What is Design to an Artist or an Architect can be very different to an Engineer. The concept of creative design can also be confused with design thinking as a process.

Many of our incoming students, their parents and general public often ask us what Design at SUTD means. New students, faculty and staff at SUTD may also have heard of the term "Big-D framework" but may be unsure of what this framework is all about.

This article aims to shed light on what Big-D means at SUTD, why it is important for the learners of the future to embrace design thinking as a way of learning, and our reflections on conceptualizing and adopting the Big-D framework in SUTD's curriculum and pedagogy. We hope that this article gives an introduction and overview of Big-D at SUTD.

WHY BIG-D FRAMEWORK?

The teaching and learning landscape across the globe is changing to embrace more student-centric approaches. Learning in higher education is no longer limited to content knowledge and application. Twenty-first century skills such as communication, collaboration, critical thinking, digital literacy, creativity, innovation and entrepreneurship are becoming essential key graduate attributes. To address the new requirements of graduates, universities across the globe are pursuing varied approaches to suit their educational contexts.

Longstanding universities that are typically lecture-based, attempt to approach this by incorporating active learning activities or courses in the existing teaching practices. For instance, Professor Eric Mazur and colleagues from Harvard University developed the clicker system in the late 90s to engage students in peer interaction and learning during lectures. The reason for gradual changes and measured modifications to existing lecture methods is often because it is very resource intensive to transform the entire system to suit the new teaching methods. To consider an example, the cost of rebuilding lecture theatres to collaborative learning environments can be exorbitant. Also, there can be discipline specific needs.

"Learning in higher education is no longer limited to content knowledge and application. Twenty-first century skills such as communication, collaboration, critical thinking, digital literacy, creativity, innovation and entrepreneurship are becoming essential key graduate attributes."

To address these challenges, there is now a growing trend that departments/colleges in traditional universities embrace teaching methods and curriculum that are suitable for specific disciplines in niche courses or departments as the *signature pedagogy* [1]. Shulman defines *signature pedagogies* as teaching methods that are discipline specific to prepare people for a particular profession, imbuing not just the knowledge but also the skills and values pertaining to a particular profession. Such signature pedagogies often become established as unique models of teaching in universities or colleges. For instance, Lee Kong Chian School of Medicine and Duke-NUS Medical School from Singapore embrace Team-based Learning as their signature pedagogy. Harvard Business School uses the Case Method.

The idea of *signature pedagogy* can be extended to *institutional signature pedagogies*. Singapore University of Technology and Design could be said to be in this category. What is unique about SUTD is that we do not prescribe to one particular teaching method or strategy. Instead, we embrace any and all relevant teaching strategies, activities and methods which encapsulate active learning, often in the form of design projects. Design projects are not just about using projects in learning as a supplementary material or as an extended application of learning. It is using projects to drive learning. Design projects integrate different aspects of active learning methods such as design-based learning, studio-based learning, and problem-based learning as a potpourri. The essential factor in Design projects is that there is Constructive Alignment of teaching activities to learning outcomes and assessments.

The fundamental reasons for embracing design-centric, project-based active learning is that over three decades of literature have shown that active learning leads to desirable outcomes such as deeper learning, more engaged learning, increased motivation of student learning and acquisition of 21st Century skills beyond the content knowledge [2-5]. The framing of SUTD's pedagogy was also influenced and inspired by MIT's Technology-enabled active learning as SUTD was set up in collaboration with MIT [6].

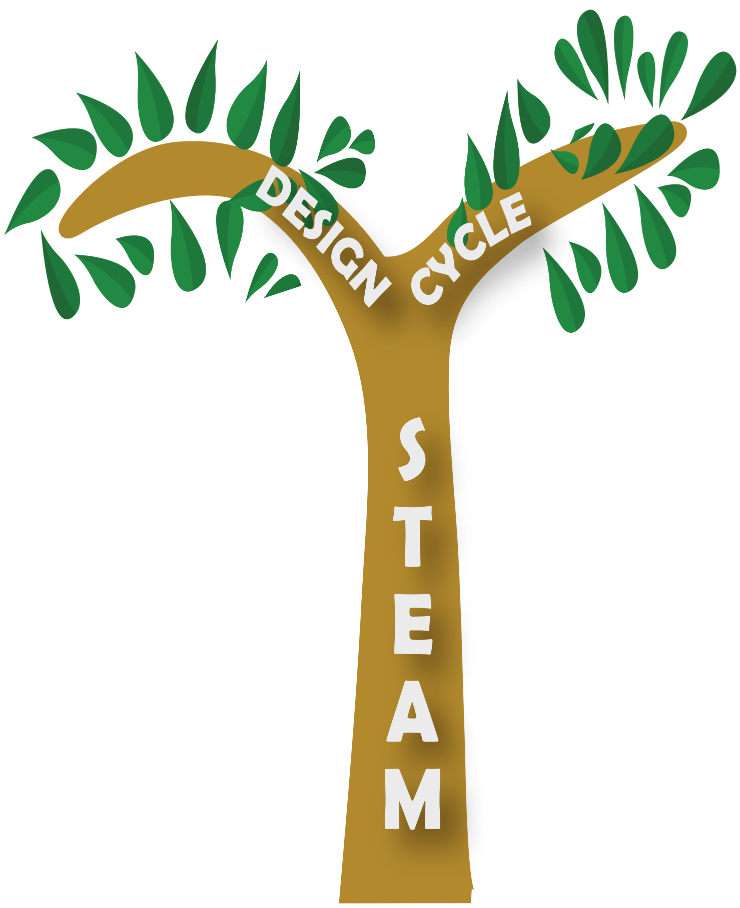
The concept of design-centric, project-based, active learning stems from the Social Constructivist learning theory that learning involves building of own knowledge, connecting new ideas, experiences, knowledge to existing ones, in collaborative learning environments [7]. In other words, learning can be realized through (a) Learning by doing, (b) Learning in teams, and (c) Learning to apply in real-life contexts which are complex and multi-disciplinary, and this is what SUTD's education exemplifies. The next sections elaborate the theoretical and practical aspects of Big-D framework underpinning SUTD's pedagogy.

THEORETICAL PERSPECTIVES OF THE BIG-D FRAMEWORK

According to the founding President of SUTD and Emeritus Professor Tom Magnanti, Design at SUTD refers to Technical Design. Technical Design looks at design as a process, where we want our students to go through the whole value chain of design, right from conceptual sketching, to coming up with several ideas, prototyping, even making mistakes and learning from these mistakes, to trying to understand why we fail, figuring out possible solutions, optimizing this, to eventually developing a working product or system or services and bringing it to manufacturing and even considering maintenance in the long run. So it involves the whole life-cycle of Design to Development to Evaluation for continual improvement. In this process, aspects such as creativity, innovation and entrepreneurship are also inculcated and nurtured. We can consider this perspective of Design at SUTD to be one side of the coin - or some may consider it as the horizontal axis.

The flip side of the coin, or the vertical axis is the inculcation of fundamental knowledge and skills. In order to be able to design, our students need a strong foundation in the fundamental Science, Technology, Engineering, and Mathematics (STEM) subjects. This also includes the Humanities, Arts and Social Sciences, which we think is essential for our students to have right from the first semester. Now, why do we need this foundational year? Often, we come across parents and students comparing SUTD's university curriculum with other universities and suggesting that they would prefer to take the shortcut of being able to do the disciplinary subjects right from first year. But we alert them that this can be short-circuiting and detrimental in the long run. Understanding the basic principles of science is very critical to Engineering and Architecture work, so that students are able to appreciate the nuances to design effective systems, services and processes properly.

For instance, all of us know that what we read in theory can be very different in practice. This is because, reality adds other contextual nuances and considerations, which are often filtered out in formulating a theory. Let us consider an example of designing a water pump. While students may be able to design on paper using a formulae, they may realize that factors such as soil composition and environment could contribute to the effectiveness of the pump in reality. This may also require



SUTD'S T-SHAPED BIG-D FRAMEWORK

> "We need to amalgamate experiences and views across various disciplines. Not just the hardware aspects of engineering and architecture but the software as well"

a cultural perspective. Thus, in order to be able to design an effective pump, we need to often consider the contextual situations and be able to apply our fundamental knowledge in that situation.

As our prime minister, Mr. Lee Hsien Loong says, "We need to amalgamate experiences and views across various disciplines. Not just the hardware aspects of engineering and architecture but the software as well" [8].

However, our first year students come from varied backgrounds. Some may have taken Physics, and some not. Some may come from the A-level route and others from the polytechnic route. Thus, the vertical axis of Design at SUTD, that is the first year at SUTD, provides the fundamental knowledge and skills which is critical for higher learning and work. In other words, it is a necessary investment to prepare ourselves to be future innovators and societal leaders. Imagine what may be the impact without the proper foundation. While the differences may not seem apparent immediately, logic tells us that proper foundation will be critical for long-term sustainability.

In a nutshell, Design at SUTD, is about having the fundamental knowledge and skills to provide a whole value chain of design and having the competencies to actually design hands-on. This is often referred to as the T-shaped education [9]. We define this theoretical perspective to be the "Big-D" framework.

IMPLEMENTING THE BIG-D FRAMEWORK AT SUTD

The question is how do we operationalize the theoretical perspectives of the Big-D framework, and bring this alive in the form of teaching of learning so that our students are better prepared for higher learning and future work? In other words, how can we teach design and get our students to embrace design as their way of life? If we simply conduct a class of what is design thinking and design innovation, students may not be able to apply these in real-world situations.Transferability of knowledge and skills in the form of application is often a challenge.

So our aim is to get our students to be able to use design and technology in developing systems, products, processes, be it in the field of engineering or architecture as part of their education at SUTD. To inculcate design in student learning at SUTD and implement the Big-D framework, we focus on our pedagogy. In particular, (i) Curriculum, (ii) Instructional Materials, and (iii) Teaching and Learning.

i. Curriculum

Learning and long term retention of knowledge requires time and practice. We may recall the saying "Practice makes perfect". According to Bruner's Spiral Curriculum theory [10], students can learn when (1) students revisit a subject, topic or theme repeatedly, (2) the complexity of the topic or the theme increases each revisit, and (3) new learning has a relationship with old learning but is put in varied contexts. Our implementation of the Big-D framework aligns with this theory. Students at SUTD are required to engage in design projects in almost all of their courses.

These projects may be within a course (1D), across courses in the same Term (2D) or across courses spanning different Terms (3D) and even outside classroom and curriculum (4D) [6]. The complexity of the projects increase from 1D to 4D projects, and these projects are all geared towards getting the students to work in teams to apply the knowledge they have learnt from the various disciplines to solve real-world issues that are complex and authentic (Figure 1). Example of these projects are given in Table 1.

1D projects are projects within a single course and this can be actual projects or active learning experiences such as the case of the Virtual Labs in the Biology course. 1D projects can be seen to be the stepping stones to more complex project works at SUTD. The next level of 2D projects gets quite interesting, as we need to integrate different concurrent courses together. So let us say students have learnt various courses in Physics, Chemistry, Maths and HASS in a Term. The 2D projects could be to design a bio-fueled rocket so that students could put together the various concepts and skills learnt across the concurrent courses. In the next level of 3D projects, students revisit and build on a project that they have worked on in a previous Term, and at times, these projects can take the form of Capstone projects. The distinction is that 3D projects involve synthesis of learning and application of knowledge and skills from courses across Terms or years. Capstone projects are epitome projects scoped in collaboration with the industrial partners and a key requirement is that the team members will have to come from different pillars. So the Capstone projects add another dimension to project work in terms of team composition. The 4D projects are essentially projects outside for classroom or curriculum, and basically, student-driven, and this adds the dimension of being self-directed to be able to

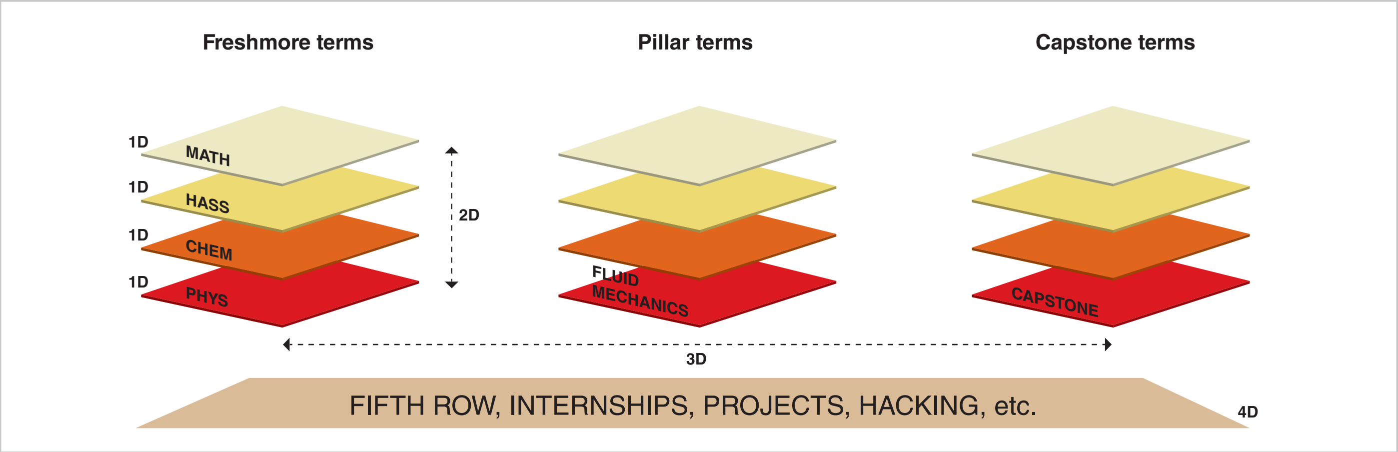


Figure 1. Big-D Implementation at SUTD

Category of Design Projects	Theme	Course	Reference
1D project	Using Virtual Lab Simulation to teach Biology	Introduction to Biology	EduSCAPES, 2018
2D project	Designing a bio-fueled rocket	Physics, HASS, Math, Chemistry	EduSCAPES, 2017
3D project	Biodesigning Health Technologies	Biodesign courses that take in students from various years and pillars, including exchange students and in partnership with a hospital	EduSCAPES, 2019
4D project	Designing and building vehicles of different types	EV Club	EduSCAPES, 2018

Table 1: Examples of Various Levels of Design Projects at SUTD

manage time and projects.

ii. Instructional Materials

SUTD pioneers Professor Pey Kin Leong and Professor Kristin Wood conceptualized the idea of Designettes at SUTD [6]. Designettes are authentic problems that require students to ideate and prototype, design a product, service or system, in a short span of time. Typically, industrial design projects take an extended period of time, and this could be in months or years. However, we cannot afford that sort of extended project time in an academic learning context. This is addressed by the use of Designettes. Designettes are authentic, real world- problems, but the problems are adapted and scoped for learning contexts such that they are simplified and yet provide sufficient opportunities to go through the design thinking process. One example of a multi-disciplinary Designette is the example of designette "Automated milk delivery system" which gets students to design and develop a system to deliver perishable milk in Singapore [6]. Students will have to use knowledge and skills learnt from various courses such as Engineering in the Physical World (a course in Thermodynamics, heat transfer and fluids), Introduction to Biology, The Digital World (a course on Programming and Controls), and the Systems Worlds (a course on Matrix and Optimization).

iii. Teaching and Learning

All of the design projects (1D to 4D) involve teamwork and students learn through engaging in project work while being supported, mentored and facilitated by a team of faculty members and graduate teaching assistants, in addition to support staff members.

An important point to note is that these projects are not merely supplementary to the main curriculum. The projects are part of the curriculum and the projects drive the learning process and often, the projects run in tandem with the coursework. Thus, the projects are weaved in together with various other pedagogies such as flipped learning and mini-lectures that introduce high-level concepts.

There are ample opportunities for the faculty to brief and mentor the students. Each course run is 14 weeks. So in the initial two weeks, the faculty members would brief about the design project work and explain the requirements and expectations. Over the subsequent weeks, they will conduct lessons which complement and help the students in the project work. By week 6 or 7, which is the mid-point of the course, the faculty members would have the teams presenting their initial ideas so that they could provide prompt and constructive feedback. Teams may also need to submit plans and reflections as part of their assessments. Often, design projects are assessed through final presentations where teams will present their design projects, in the forms of posters, presentations, prototypes and demonstrations. These final presentations are typically held in public learning spaces and involve review by peers, faculty, industrial partners and even public. So the assessments are both formative and summative and a heavier weightage is given to formative assessments; that is assessments conducted during the learning process itself. This removes the overemphasis on the typical or traditional final written exams.

To ensure that our students are supported in design-centric projects, we require all our first year students to undertake a course called "Introduction to Design and Innovation". This is a general course that teaches students what design means, and introduces them to systematic design thinking approaches and tools, so that our students are well-equipped. Students are also coached on working collaboratively in teams, and this workshop gets students to understand their own team working style, that of their team members and to come up with a collaborative work agreement and plan. In addition to this, students may also attend other useful complimentary courses which introduce them to software tools and coding taught by faculty, staff or even students help-groups.

OUTCOMES AND IMPACT OF BIG-D FRAMEWORK

Typically, SUTD students have to engage in at least one project in each course. So in total, students could complete 20-25 projects in the 3.5 years at SUTD. One could work out the rich learning experience that students will gain out of this methodical and well-supported education. SUTD graduates are quite well-versed to be a team member or leader when given a problem or task that may or may not be familiar to them. This can also explain why our graduates indicate that they are confident and well-prepared for work and higher learning and why employers of SUTD graduates are all satisfied with SUTD's learning experience in the annual graduate survey.

Our graduates have a strong foundation and they know how to apply these knowledge and skills in varied, complex, authentic real-life problems effectively. Reportedly, SUTD graduates get higher pay than their counter parts upon graduation [11]. Our engineering and architecture degrees are accredited by the respective professional accreditation body. In addition, many of our students go on to start up their own companies post-graduation and often these ideas arise from the project work that they engaged in.

To top it off, a recent MIT report [12] identified SUTD to be the top emerging engineering university in the world, and this is in comparison of world–renowned universities (Figure 2). These data points of outcomes indicate that we are in the right trajectory in embracing Big-D framework.

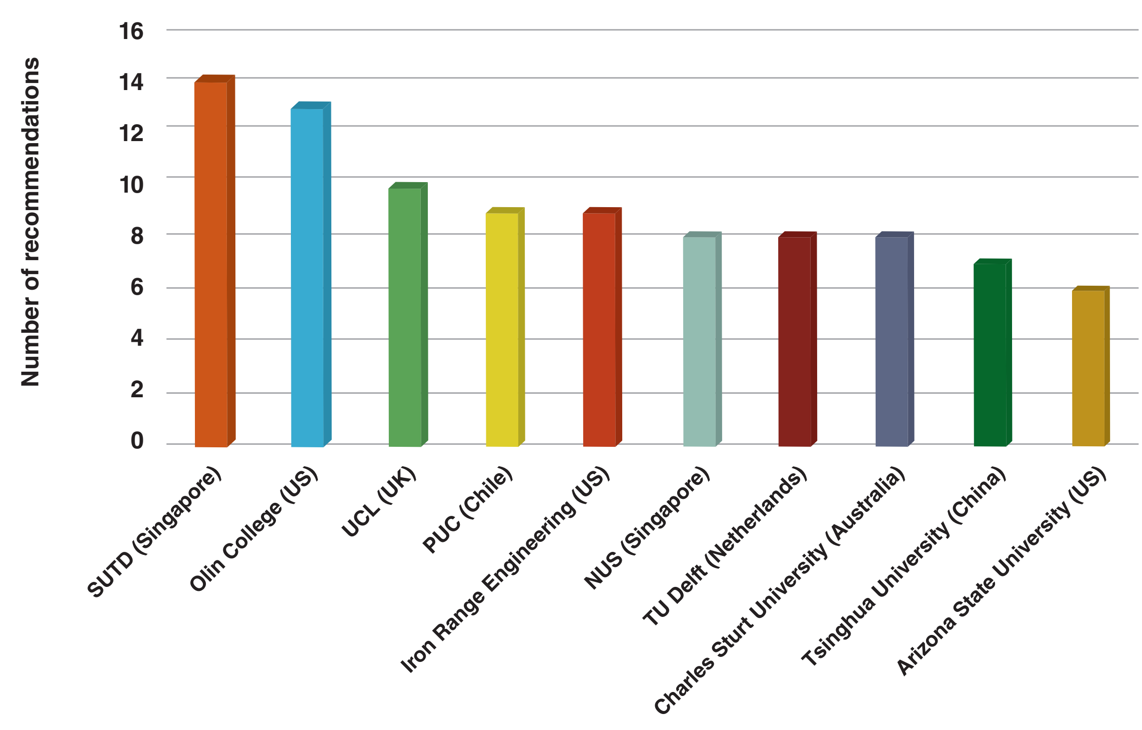


Figure 2. The 10 most frequently-identified 'emerging leaders' in engineering education, out of 89 universities from 27 countries [12]

FUTURE DIRECTIONS OF BIG-D FRAMEWORK

In the first ten years, we have been focusing on designing, and implementing the curriculum and pedagogy. We are now more seasoned and experienced, and we continue to improve by fine-tuning the curriculum to keep pace with the industry and societal needs. In addition to curriculum refinements, we explore the boundaries of teaching innovations. For instance, many of the current design projects require peer-to-peer learning in person. With the use of advancing technologies, we would like to explore peer-to-peer learning, cohort-based learning beyond classroom in the cyber-space. Perhaps students can learn across geographical distance and in virtual spaces as a team. Another possibility is that we could explore the use of AI-driven assessments and feedback. Many of our faculty members are engaged in such teaching innovation projects funded by Office of Undergraduate Studies and supported by units such as Learning Sciences Lab. We also embrace Scholarship of Teaching and Learning to continually evaluate our teaching practices and innovations to promote teaching excellence so that our students get the best teaching. As noted in the MIT-NEET report [12], educational research is more prominent at SUTD than at most research intensive universities. Moving forward, we hope to empirically evaluate the impact of the implementation of Big-D framework on student learning, and their preparedness for work. It will be useful to understand how our students value and embrace design-centric projects and how it has transformed their learning - not just in terms of their satisfaction but in terms of their actual skills and application.

CONCLUSION

Overall, Big-D-framework at SUTD is well-grounded on educational theories, and implemented effectively at SUTD to suit the context of preparing our students to be leaders and innovators to serve the societal needs. The various indicators from students, industries, academic partners, accreditation bodies and external observers provide strong support for the Big-D framework at SUTD. We continue to reflect and evaluate our own programs to ensure that we provide the best educational experience for our SUTD graduates. In other words, we continue our efforts in redesigning and transforming undergraduate education in Engineering and Architecture to prepare students who are ready for the world of Volatility, Uncertainty, Complexity and Ambiguity.

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Professor Pey Kin Leong *(right)* is the Associate Provost for Undergraduates Studies and SUTD Academy. He is a well-established industrial practitioner, researcher as well as academic. He has a keen interest in technology enhanced, design-centric and project-based learning and has been a pioneer in establishing SUTD's pedagogy.

BENCHMARKING EDUCATIONAL DEVELOPMENT CENTRES IN SINGAPORE'S UNIVERSITIES

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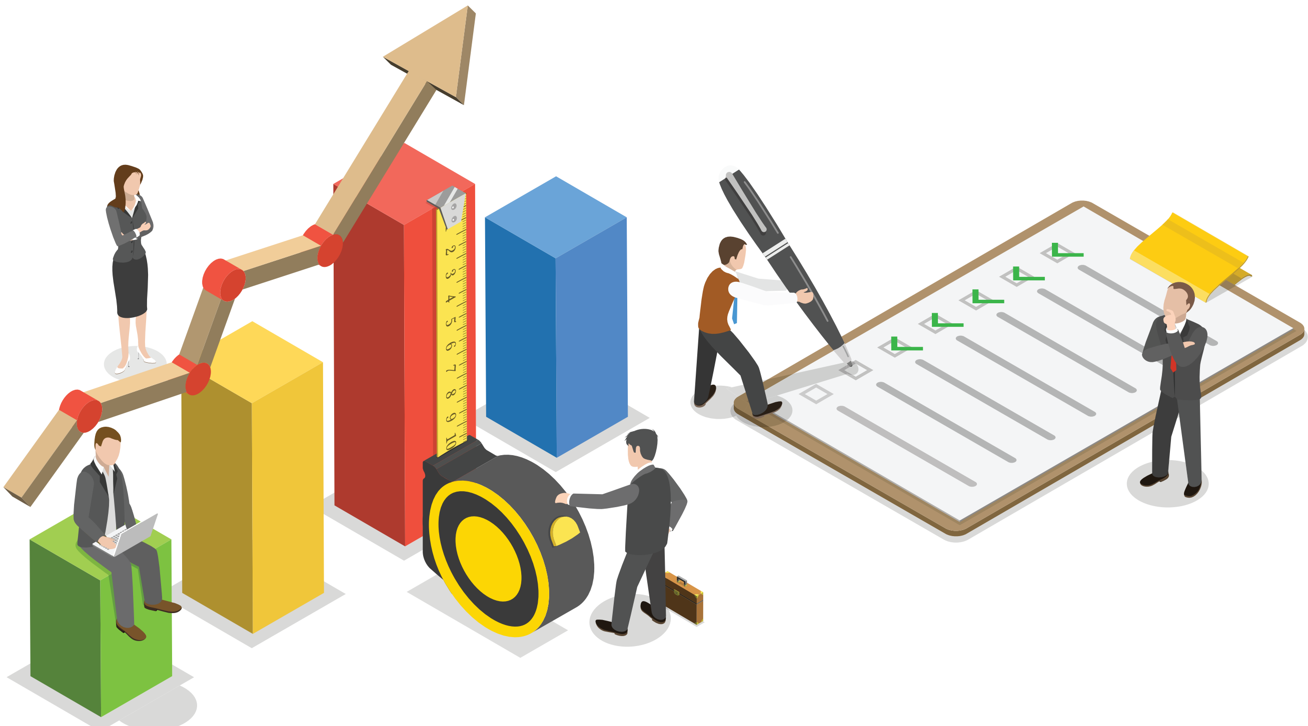
PROF. PEY KIN LEONG, OFFICE OF UNDERGRADUATE STUDIES (UGS) & SUTD ACADEMY



This article presents reflections from an explorative benchmarking analysis of Educational Development Centres (EDCs) in the public universities of Singapore. A primary motive to undertake this project was to understand if SUTD's educational development centre, Learning Sciences Lab (LSL), is on the right trajectory in its educational development work in comparison with the wider community.

To set up LSL, we used a multi-pronged approach to understand the needs of the stakeholders at SUTD. This included conducting several interviews, focus group discussions and surveys with various stakeholders such as key leaders, faculty, staff members and students. We then took the strengths and weakness of our SUTD context and our priorities into consideration in designing the educational development activities to align with the needs of the stakeholders as well as the vision and mission of the university. The blueprint of educational development at SUTD was shared in the earlier newsletters (Sockalingam, 2017 & 2018).

Since it has been two years since the starting up, we felt that it will be imperative to take an outward looking approach as well, to understand the scope of educational development work nationally and internationally, to benchmark and learn from. So we started with a basic set of questions on what educational development means, what sort of activities do educational development centres like LSL in the universities from Singapore typically conduct, and infer implications of SUTD's context in shaping our future educational development programs and initiatives at SUTD.

HISTORICAL CONTEXT OF EDUCATIONAL DEVELOPMENT CENTRES

The field of educational development and introduction of educational development centres to conduct educational development work in universities is relatively young in comparison to the history of universities. While there are universities which have had EDCs for over 40 years (Gosling, 2009; Gibbs. 2013), there are still others which are yet to establish EDCs. The first EDC in Singapore was established in the National University of Singapore.

Fernandez and Márquez (2017) posit that the rationale for setting up EDCs seems to be context specific to each country and region. In many instances, national level policies seem to have led to the setting up of EDCs in universities. For instance, the 1997 Dearing report on the status of higher education is thought to have energized educational development work in UK. Quality Assurance agencies have played a key role in the establishment of EDCs in Europe, Australia and Spain (Di Napoli et.al., 2010). As a result, many of these countries have made it compulsory for all faculty members to undergo pedagogical training and hence universities have set up their EDCs (Trowler & Bamber, 2005; Lindberg-Sand & Sonesson, 2008).

Fink (2013) reports a geo-specific progression of EDCs and remarks that Asian countries typically tend to be at the basic level of educational development work where there is little or no activity. A rare systematic review of faculty development in Asia by Phuong, Duong, and McLean (2015) suggests that faculty development in Asia is more predominant in English-speaking Asian countries such as Vietnam, Singapore and Malaysia.

Overall, educational development work seems to be fairly young in Asia when compared to the United States, European countries and Australia.

DATA COLLECTION AND ANALYSIS

To classify educational development work, international educational development literature was referred to (Sockalingam, 2018). To compare universities across Singapore, we used publicly available official data from the web portals of the six public universities in Singapore, namely (1) Nanyang Technological University (NTU), (2) National University of Singapore (NUS), (3) Singapore Institute of Technology (SIT), (4) Singapore Management University (SMU), (5) Singapore University of Social Sciences (SUSS), and (6) Singapore University of Technology and Design (SUTD), accessed in August 2018.

In addition, we conducted an online survey with the various EDCs during the period of July to August 2018. The survey consisted of a mix of multiple choice questions and open-ended questions, and queried on (1) the various activities of the centre, (2) with ranking of the top 3 activities, (3) indication of compulsory activities, (4) identification of primary stakeholders that they serve (students/faculty/staff), (5) identification of three support centres they collaborate with, (6) participation level in centre activities, (7) if and how the EDCs measures the impact of educational development work, (8) challenges faced, and (9) future directions. Institutional Review Board (IRB) clearance was obtained on the research protocol. Mixed method analysis was used to analyse and summarise the data.

RESULTS

I. Classification of Educational Development Work

According to the international Professional and Organizational Development Network (POD Network, 2018), educational development refers to developmental work undertaken in areas of teaching and learning towards the enhancement of education. It can be classified as (1) Instructor (Faculty/Graduate Student/ Postdoc) Development, (2) Instructional Development, and (3) Organizational Development. Chalmers, and O'Brien, (2004) clarify that educational development is concerned with the development of both teaching and the environment in which teaching occurs. Leibowitz (2014) introduces the people factor and adds that educational development, sometimes referred to as academic development, focuses on academics, their learning and achievements (Leibowitz, 2014).

Felten, Kalish, Pingree, and Plank (2007) suggest including a fourth dimension of Community Development to this. Since there is an increasing inclusion of students in educational development work, Student Development could also be added to this list. Combining these is the proposal for a classification of educational development as depicted in Table 1 (Sockalingam, 2018).

While the five types of developmental work focus on different aspects of teaching and learning, all of these are essentially about supporting faculty in teaching so that it eventually helps students to learn better. Chalmers and O'Brien (2004) argue that the role and ultimate responsibility of an educational development centre is to work with university teachers and staff members on their educational development, so that by developing themselves, their students benefit. The focus is on learners and learning (as reflected in our LSL logo).

II. Educational Context and EDCs in Singapore

To start with the educational context, we collated an overview of statistics (Table 2) from the centralized educational development centres in the six universities. This was to compare apples to apples. LSL is a centralized unit, common to all pillars and clusters in SUTD. In large universities such as NUS, there are satellite centres such as those in the medical schools. However, this study does not include the satellite centres.

One of the survey questions listed out 18 common educational development activities practiced internationally and asked EDCs to indicate activities their centres engaged in and to rank the top three. Of these 18, 8 were on Instructor Development, 4 on Community Development, 2 on Organizational Development, 2 on Instruction Development, and 2 on Student Development. All of the six EDCs indicated that they were engaged in 4 to 5 types of the five educational development activities.

The most highly ranked category was Instructor Development, and this was followed by Organization and Community Development. Instruction and Student Development was the least commonly cited and ranked. In general, the nature of educational development work seems to depend on the type of university. For instance, a university focusing on adult learners catered to Student Development whilst most others did not.

The six EDCs, known by different names, (Table 2), consist of two main groups of staff/faculty members. They are the educational developers and administrators. This study considers educational developers to be members who are functionally engaged in educational development work (Table 1) regardless of their official employment status as staff or faculty members. The other group, administrators, are primarily involved in administrative support and functioning of the unit, such as in organizing events. The size of EDCs in Singapore typically range from 2 to 18 members. In general, most of the educational developers were faculty members who may be seconded to the EDCs. Since Instructor Development is a key function of EDCs, Table 2 focused on the number of educational developer to instructor ratio. Instructors in our case can be in the form of full time faculty, associate faculty and graduate instructors. The ratio was very varied across the universities, and further research is needed in this area.

Unlike UK or European countries, there is no requirement for higher educational faculty members to have completed teacher training in Singapore. Each university has its own ways of ensuring the quality of faculty members. So the EDCs were queried if their programs and services are mandatory and the extent of participation in EDC activities. Interestingly, only one of the activities related to Instructor Development was made compulsory in five of the six EDCS. This was the orientation courses for new faculty and graduate teaching assistants. Also, one other university has made it compulsory for all faculty to be prepared for online teaching. None of the other activities are compulsory in all the six universities. One of the six universities indicated that none of the activities are compulsory.

The six EDCs noted that participation in activities is varied and typically highest for compulsory activities. Participation in most other activities can range from low to medium, and depends on various factors such as time and interests, with some EDCs noting that they would like to have more participation. Typically, teaching track faculty members were reported to be more participative than research/tenure track members in EDC activities.

The EDCs were asked to indicate three of their close collaborators. Of these, Educational Technology and Library were commonly cited to be close partners by all six. In fact, three of the six EDCs were once formed in partnership with Educational Technology units, and there is often an overlap in activities. Others collaborators include Teaching Academy, Office of Students Admissions, Research Centres, Office of Graduate Studies, Office of Advancement and Development, and Academic Facilities.

All EDCs indicated that they used end-of-activity surveys to measure participant satisfaction and collate feedback on EDC activities. Focus groups, anecdotal evidences, and open-ended feedback are used as additional measures. About 50% of the EDCs indicated having a systematic or longitudinal evaluation of specific and key activities or programs such as the Graduate Teaching Assistant training program. However, all indicated that they did not have an established holistic measurement on the impact of EDC work on teaching and learning at the university level.

When asked on the challenges faced in EDC work, all had noted changing or influencing the mind set of key stakeholders (which includes leadership, management, faculty, graduate and undergraduate students) towards educational development work. This could take the form of gaining acceptance on the importance of EDC work and educational developers as credible support agents from faculty members, being able to show the

Type of Educational Development Work	Focuses on	Examples of activities
Instructor Development	Teaching practices of individual instructors such as faculty members, graduate teaching assistants or postdoctorates - to prepare and develop the instructors in teaching.	✓ Pedagogical workshops ✓ Peer-coaching ✓ Scholarship of Teaching and Learning
Instructional Development	Course and curriculum – This is concerned with the development of programs, courses, course materials, pedagogical approach and assessment practices.	✓ Curriculum mapping and revamping ✓ Supporting instructional development of digital material course preparation
Organizational Development	Strategizing, developing policies and systems to support teaching and learning in higher education as an organization.	✓ Setting up systems and processes on faculty educational development ✓ Strategizing and shaping teaching and learning related policies
Student Development	Helping students on learning to learn and including them in educational development work	✓ Workshops on learning to learn skills, research skills, team work ✓ Students as partners
Community Development	Helping to build teaching and learning communities, facilitating learning and providing support.	✓ Holding sharing sessions such as lunchtime Brown Bag sessions ✓ Social media network ✓ Writing circles

Table 1: Classification of Educational Development (Sockalingam, 2018)

University	University Origin	EDC Origin	UG Students in 2018	Instructor (Full time, Part time, Graduate)	Size	EDC Members	Educational Developer	Administrative Staff	Educational Developer to Instructor Ratio	EDC
National University of Singapore (NUS) http://www.nus.edu.sg	1905	1996	28000	~4000 (Exclude Graduate Instructor)	Large (>10000 students)	18	9	9	1:444	**Centre for the Development of Teaching and Learning (CDTL)** http://www.cdtl.nus.edu.sg
Nanyang Technological University of Singapore (NTU) https://www.ntu.edu.sg	1991	2014	24300	1726 (Exclude Graduate Instructor)	Large	9	5	4	1:345	**Teaching, Learning and Pedagogy Division (TLPD)** https://www.ntu.edu.sg/tlpd/Pages/default.aspx
Singapore Management University (SMU) https://www.smu.edu.sg	2000	2005	8000	574 (Include Graduate Instructor)	Medium (>5000, <10000 students)	10.5	8.5	2	1:68	**Centre for Teaching Excellence (CTE)** https://cte.smu.edu.sg
Singapore University of Technology and Design (SUTD) https://www.sutd.edu.sg	2009	2016	1300	~400 (Include Graduate Instructor)	Small (<5000 students)	2	1	1	1:400	**Learning Sciences Lab (LSL)** https://www.sutd.edu.sg/learningsciences
Singapore Institute of Technology (SIT) https://www.singaporetech.edu.sg	2009	2014	6100	216	Medium	6	5	1	1:43	**Centre for Learning Environment and assessment Development (CoLEAD)** (Only internal website - no public facing website)
Singapore University of Social Sciences (SUSS) https://www.suss.edu.sg	2017	2017	14000	1000	Large	9	5	4	1:200	**The Teaching and Learning Centre (TLC)** tlc.suss.edu.sg/

Table 2: Overview of statistics from the six universities in Singapore and their EDCs

impact of EDC work, getting sufficient resources to support and sustain EDC activities, being able to grow the programs, increasing participation and balancing between generic and discipline-specific educational development programs. Another challenge noted was the lack of academic development expertise and the practice of contractual or secondment of educational developers in EDCs leading to disruptions and non-continuity.

GENERAL DISCUSSION

Overall, the results suggest that despite a brief history of less than 30 years, the EDCs in the six universities in Singapore have made significant progress in providing a wide range of activities and a holistic educational development support for their faculty, staff members, undergraduates and graduate students. We can call it "holistic" because the range of activities cover all or most of the 5 types of educational development activities.

Like most universities worldwide, the primary focus of EDCs in Singapore seems to be Instructor Development. Activities of Organizational, Community, Instruction and Student Development are yet to become more prevalent and this can be for varied reasons, which are yet to be explored in Singapore context.

> *"Unlike UK or European countries, there is no requirement for higher educational faculty members to have completed teacher training in Singapore."*

Despite the variety, participation level in these activities are reportedly low except for mandatory programs/services. Therefore, these EDCs and universities need to consider how to engage more faculty and other stakeholders in educational development, and this may be related to recognition and rewards for teaching and participation in educational development activities, as well as university level policies that emphasise the need for continual development in teaching in higher education.

Unlike UK or European countries, there is no national level policies in Singapore that require faculty members at higher educational institutions to complete teacher training. Such national level policies are noted as the reasons for existence and functions of EDCs in other studies (Kolomitro & Anstey, 2016).

A possible implication of low participation level and participation by only a sub-group of faculty members is that participation and feedback is often related to resources and support for the EDCs. So low participation could lead to lack of resource support in terms of manpower and funding. For instance, the analysis shows that the size of EDCs can be very small, with 1 educational developer serving over 400 instructors. This could lead to overstretched efforts by EDCs.

The lack of manpower in EDCs could also explain the lack of focus on certain areas of educational development such as in the areas of student development despite the possibility that this can prove to be very useful and essential for the various stakeholders of a university. So, it is worth looking into policies and schemes to recognise and reward participation in continual professional development in teaching to increase participation as well as consider the resource needs of EDCs in terms of manpower and funding.

A common challenge faced by Directors of EDCs across the universities seem to be influencing the mindset of stakeholders towards educational development. Such observations are also noted by others such as Kinash and Wood (2010), Gosling and Turner (2015) and Knapper (2016). Despite the recognition by institutions that EDCs are necessary, it is often observed that EDCs are only loosely coupled or leveraged upon for institutional strategic directions on teaching and learning (Gosling and Turner, 2015). Perhaps more could be done to involve and engage EDCs in various aspects of strategizing university policies and initiatives in aspects other than instructor development. Rather than just EDCs making it as their directions to engage the various departments, the various departments could also see how to engage EDCs.

The benchmarking survey also reveals that EDCs can do more to determine and establish the impact of EDCS on teaching and learning. Many of the EDCs in this study report that they do end of activity satisfaction survey or conduct focus groups on the EDC activities to measure impact. This would be a good start but may not shed light on longitudinal impact. For instance, if an EDC organizes a talk, it would be good to find out if and how faculty members continue to use some of the learnings in their teaching in the first place. While we do not expect every participant to find the session useful and relevant for them to implement in their work, it is good to find out if attendance has been translated to continuation or if it has an impact in some ways in the larger context.

Another point to note is that even though educational development activities are meant to enhance students' learning experiences and lead to gain in learning, this is an indirect effect. The direct impact is likely to be on teaching first and through teaching on learning. This is because our primary focus tends to be on teachers and teaching. So we may need to consider the nature of educational development activities and the expected outcomes and outputs to measure the impact rather than expecting to see an immediate impact on learning (this may be very small, compounded and take time). Overall, there is a need to build appropriate measurement tools.

RELATING THE FINDINGS TO SUTD, LSL

Having gotten a broader picture, we wanted to see how SUTD stands in comparison to this common set of data. Comparing the range of LSL activities to the proposed educational development framework reveals that LSL conducts activities in all five areas of educational development work. Table 3 provides an overview of the services provided by LSL.

We know from our LSL data that 82 % of teaching track, 37.5% of tenure track faculty and 94% of Graduate teaching assistants engage with LSL in various ways (LSL, 2018). This seems to be a fairly healthy number given that the LSL team consists of one educational developer and an administrator (before September 2019). This is a ratio of 1 or 2 staff to 200 faculty members, 200 Graduate Teaching Assistants and 1350 undergraduate students. Moving forward, it would be good to determine the extent of engagement. It can be rationalised that the quality of the engagement is likely to depend on ratio of staff to faculty, instructors and stakeholders.

To address resource limitations, LSL uses creative ways that are aligned with the SUTD context. For instance, LSL introduces and advocates Scholarship of Teaching and Learning (SOTL) as the key mechanism for continual professional development in teaching at SUTD. SOTL can be likened to design thinking in teaching. SOTL places responsibility on the faculty members to understand student needs, design suitable teaching activities, reflect and inquire on their teaching practices. While the onus is on faculty members, they can leverage on LSL and colleagues to support inquiry into teaching through collaboration and consultations. LSL creates opportunities for faculty and the wider community to share and learn on pedagogical practices. The advantages of this approach are that this ensures quality teaching, continual development in teaching and also effective and efficient use of resources.

Another innovative strategy that LSL has initiated is an Educational Fellowship Program in collaboration with the Academy of Higher Education (AHE) to build the leadership capability of senior and experienced faculty members in teaching. The Educational Fellowship Program, launched this year (2019), involves a pioneering batch of 11 faculty members undertaking a reflective journey of their teaching practices (Figure 1). The faculty members will submit their portfolio for peer recognition and validation by the international community based on AHE's framework on teaching and learning in higher education. This program will lead to international professional recognition in teaching. In addition, the critical differentiating factor of the SUTD program is that the first batch of fellows will be the champions in mentoring the next batch of participants. This way, there is continual and community-based learning and reflective teaching.

In general, instead of using top-down, policy driven approaches to "mandate" training, LSL attempts to a build up a ground up approach of developing a teaching culture at SUTD. This, we feel, is likely to be more impactful and sustainable. Also, the focus moves from teaching, that is how to teach, to learning, that is how do I know that my students are learning if I teach in a certain way.

Area of Educational Development	Examples of Current LSL activities
Instructor Development 	✓ Teaching Certificate Program for Graduate Teaching Assistants ✓ New faculty workshop on "Teaching at SUTD" ✓ Faculty workshops such as "Teaching Methods for Active Learning" ✓ Peer coaching on teaching ✓ Consultations and collaborations on educational projects
Instructional Development 	✓ Consultations on chunking curriculum for Flipped learning, blended learning ✓ Formative/summative assessments such as rubrics
Organizational Development 	✓ Forming Faculty Educational Developing Committee and consulting on key initiatives ✓ Strategizing and implementing Educational Fellowship Program ✓ Systematic studies on benchmarking educational development centres/evaluating teaching course implementation
Student Development 	✓ Engaging "Students as Partners" in creating teaching materials ✓ Including students in educational talks/sessions ✓ Organising "Learning to Learn" workshops for students
Community Development 	✓ Sharing sessions on teaching and learning ✓ Annual Pedagogy Day ✓ Annual Pedagogy Newsletter ✓ Quarterly communications ✓ Website/Blogsites/Online Resources

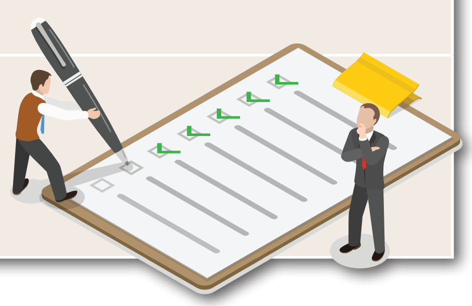


Table 3: Educational Development at SUTD

Figure 1. First Cohort of AHE fellows

LSL works with various offices, pillars and clusters which offer diverse academic programs in pedagogical initiatives. For instance, there is increasing number of self-initiated pedagogical interest groups at pillar/cluster levels over the 3 years. LSL plays a role in co-organizing, keeping track of the overall initiatives at the university level, and connecting the various stakeholders on key projects. One example is the compilation of all the various pedagogical publications from SUTD. Another is strategizing and publishing this thematic annual pedagogical newsletter. In this way, LSL serves as a coordination and connecting point for pedagogical initiatives, and shifts educational development from individual to community-based.

LSL also works with faculty members and students to co-create teaching materials and educational resources and this sort of mutual contributions lead to shared learnings on pedagogy. For instance, LSL works with faculty members in framing their work on pedagogical theory and literature and introduces them to new aspects of pedagogical developments. Similarly, SUTD faculty members are also conducting cutting edge innovations in teaching and by working with LSL team, help the LSL team to learn these technologies. So there are mutual exchanges and learning, and educational development shifts from silo-practices to collaborative practices. In addition to these, LSL plans to work with the various stakeholders such as Human Resources to see how else we can promote participation and engagement in continual development of teaching.

Overall, LSL is taking a different approach to educational development from the traditional approach of getting faculty members to attend a series of training workshops to complete a road map of training courses and clocking the training hours towards a certification. Instead, LSL attempts to engage the SUTD community in educational development as an organization by engaging in all of the 5 educational development activities, using design-centric, project-based, teaching–inquiry projects to enhance the quality of teaching and learning so as to better support our learners. Many of LSL initiatives reflect characteristics of mature EDCs described by Gibbs (2013). According to Gibbs (2013), a shift of focus from (1) Instructor to Community Development, (2) classroom to learning environment, (3) teaching to learning, (4) change tactics to strategies and (5) quality assurance to enhancement are signs of maturing teaching and learning centres, and LSL seem to be in the right trajectory. This, of course, is not possible without collaborations with various pillars/clusters/offices within SUTD and with EDCs from the other universities in Singapore.

CONCLUSION

The benchmarking exercise is conducted to ascertain if we are in the right trajectory and the indications seem to be that we are. It is not meant to compare and compete with other universities; to do and have what others have to compete. The educational context is an important consideration in making the right decisions and setting the directions. Given that SUTD is comparatively smaller and younger than some universities, and has a unique pedagogy that focuses on design-centric project based learning that is multi-curricular and leveraging on design and technology, our approach to educational development has to be tailored to this.

Hence, our approach to strategizing LSL initiatives aims to empower faculty members and stakeholders, and create opportunities for them to excel, inspire and learn from each other to promote enhanced teaching and learning. We focus on building a work culture of collaboration and creativity and embrace design thinking approach in the form of Scholarship of Teaching and Learning. What we can also gather from this systematic analysis is a framework to classify educational development work (Sockalingam, 2018) so that we can monitor and evaluate the outcomes and outputs on the various categories of educational development. The framework can also help us to estimate the resources and plan suitable initiatives needed.

This study also goes to show that we take a scholarly approach to our administrative work to assure and improve the quality of support for teaching and learning at SUTD.

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REFLECTIONS

IMPLEMENTING A CASE-BASED, EXPERIENTIAL LEARNING PEDAGOGY FOR ENGINEERING STUDENTS AT SUTD

PROF. PETER JACKSON AND DR. YING XU, ENGINEERING SYSTEMS AND DESIGN (ESD)

INTRODUCTION

In this note, we describe a current effort within ESD to implement an extended case-based, experiential learning approach for teaching supply chain logistics. This approach has been pioneered at SUTD by Prof. Shrutivandana Sharma in our core course Manufacturing and Service Operations, and elective course Supply Chain Management. The approach features pre-built simulation models of multi-stage operations, constructed as competitive games, as well as hands-on physical simulations designed to illustrate principles of controlling flow in dynamically-chained operations.

The mathematics of describing and analyzing the system phenomena of supply chains can be quite abstract and complex. Students can certainly study and memorize formulae of these systems but with very little intuition about the behavior. The time lags, capacity constraints, multi-stage dependencies, and stochastic complications result in surprising behaviors. The experiential approaches are designed to drive home the intuition behind these phenomena. It has also been our delight to find that when students are presented with a complex problem in a game setting, they evidence a hunger to learn practical techniques to tackle the problem. As instructors, then, we face a demand-pull situation in which the students are primed to appreciate mathematical approaches to these complex problems. Prof. Sharma, for example, bases students' grades on how well they apply the mathematical approaches to game situations.

> "The approach features pre-built simulation models of multi-stage operations, constructed as competitive games, as well as hands-on physical simulations designed to illustrate principles of controlling flow in dynamically-chained operations."

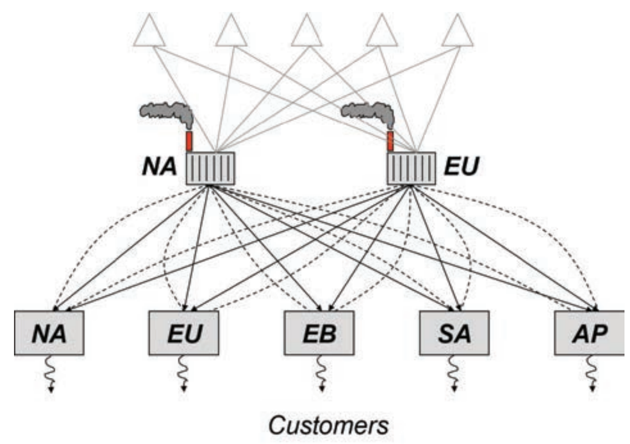

Figure 1. NOVA Corporation Global Supply Chain

A NEW ESD ELECTIVE: SUPPLY CHAIN DIGITALIZATION AND DESIGN

We have extended this tradition of experiential learning in supply chain logistics with the introduction of a new elective in ESD, Supply Chain Digitalization and Design, first offered in Term 8, 2019. We have just completed the first half of the course which features these techniques. The second half of the course will build on this foundation with a more business management orientation. We did not develop these materials: they are the product of years of collaboration between our colleagues at Cornell University, the University of Michigan, and the College of William and Mary. One of the co-authors has had the advantage of co-teaching using these materials at Cornell. So the challenge we faced at SUTD was in implementing and adapting the materials to suit our purposes. We will highlight those challenges and preliminary indications of success at the end of this note.

THE NOVA COMPANY CASES

The backbone of the course material is a sequence of cases describing the evolution of a fictitious multi-national corporation called NOVA. These cases provide the backstory and raw data as context for understanding the issues in supply chain design and management. As in business school cases, the story is told from the perspectives of different individuals in the organization: the chief executive officer, and the heads of finance, marketing, engineering, manufacturing, and logistics. Many of the prominent initiatives in supply chain management from the past quarter century, such as outsourcing, lean manufacturing, mass customization, cross-docking, point-of-sale demand capture, and more, are woven into the story. The storyline thus provides a rich context for the instructor to draw out the importance of, and relations between, these different initiatives.

THE NOVA GAME

Beyond the backstory, however, and this is particularly important for inclusion in an engineering curriculum, the business situation is simplified and scaled so that explicit simulation models can be developed to mimic the day-to-day operations of the entire global supply chain and for these models to be comprehensible for students and fast in execution. Whereas modern supply chains encompass hundreds of thousands of products (even millions, in the case of Amazon) with thousands of process steps (semi-conductor manufacture), months of manufacturing lead time, and hundreds of hand-offs between different organizations, the NOVA corporation is described using only ten products, ten raw materials, three manufacturing process steps, single-day lead times, and a simple global network consisting of two factories and five distribution centers. The advantage of this scaling is that phenomena which can take months to reveal themselves in the real-world (industrial boom and bust cycles, for example) show up within a few days of game play.

“The storyline thus provides a rich context for the instructor to draw out the importance of, and relations between, these different initiatives.”

Game play and simulation are enabled in several ways. In this note, we focus on the major experience for the students, playing the NOVA Game. The Game is a multi-player, networked game in which teams of students operate replicas of the NOVA supply chain. Figure 1 illustrates the supply chain with two factories, one in North America (NA) and one in Europe (EU), and five distribution centers, in North America (NA), Western Europe (EU), Eastern Europe (EB), South America (SA), and Asia-Pacific (AP). Students on each team are organized into

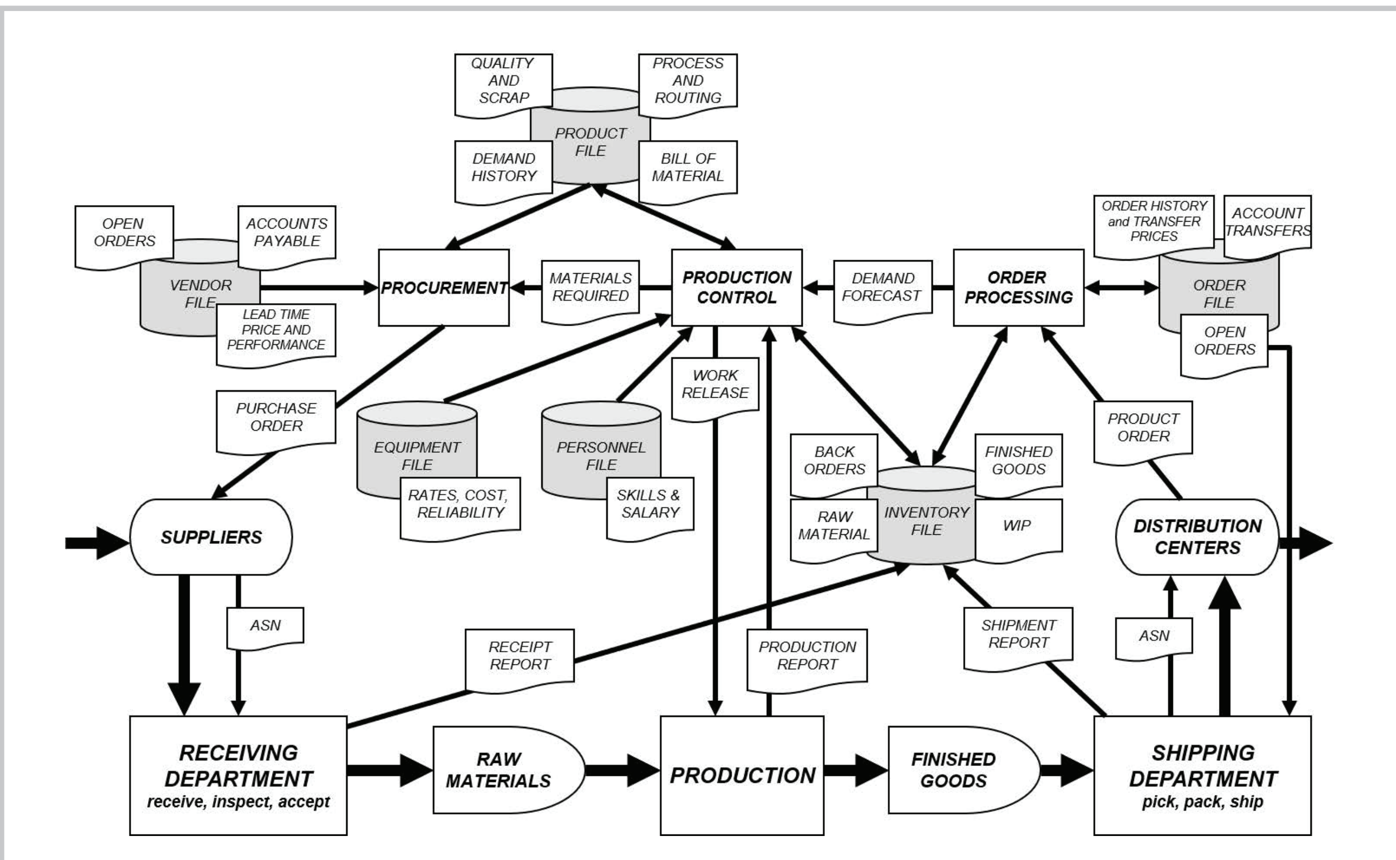

Figure 2. NOVA Corporation Global Supply Chain

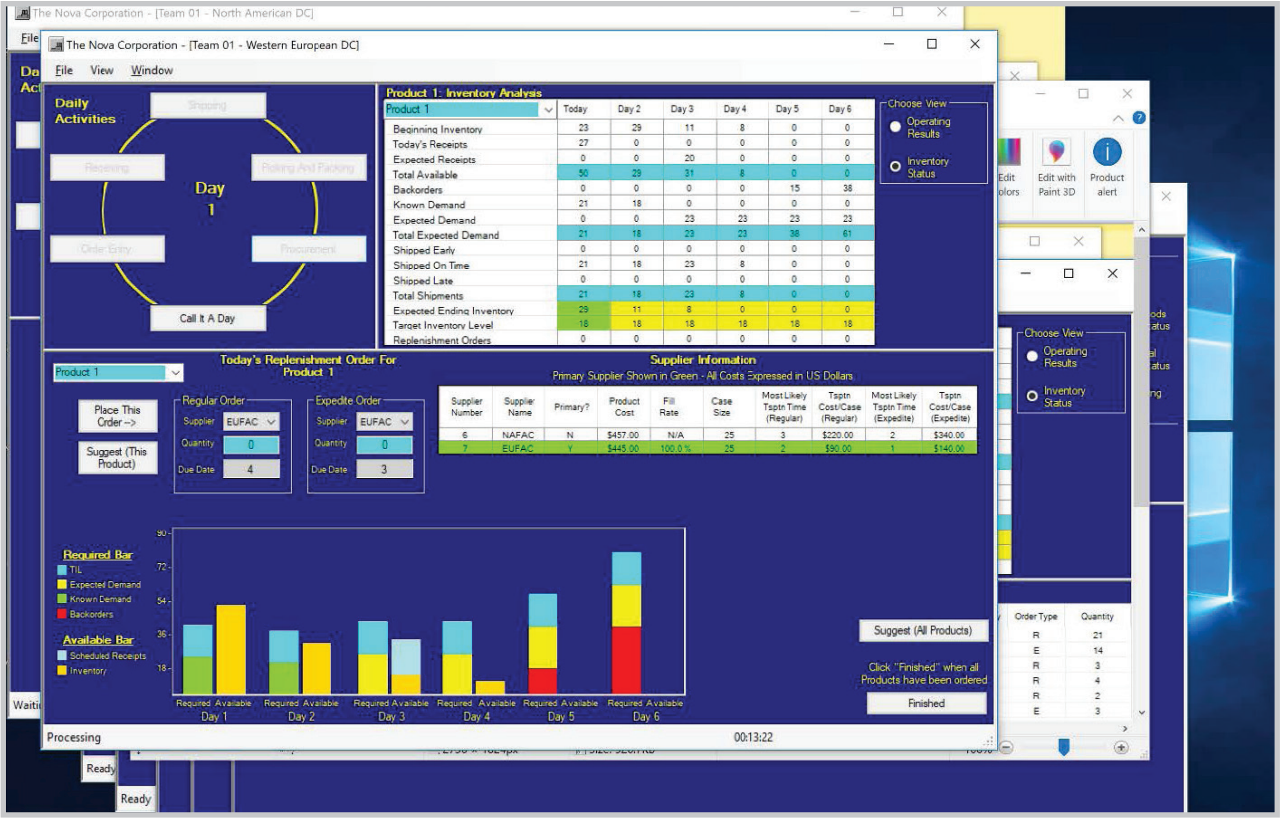

Figure 3. Decision Support Interface for Procurement Activity

sub-teams with two or three students assigned to manage operations at each location. We accommodated a class of over 40 students using three replicas of the supply chain.

In the background, networked across all seven locations, the game software manages the complexity of information and material flows. Figure 2 depicts a high-level view of the material flows and information exchanges for one of the factories. In this initial game, the production control and material logistics are all handled using traditional Material Requirements Planning (MRP). One of the main purposes of this game experience is to reveal the shortcomings in this traditional approach.

The game software features a user-friendly interface which guides students through the daily decision opportunities. For example, Figure 3 is a screenshot showing the daily activities in operating a distribution center (order entry, shipping, receiving, and procurement) as a cycle terminating with the "Call it a Day" function which signals to the game server that all activities for the day have been completed. Once all the daily activities for each sub-team (i.e. each location) have been completed, the server enacts the exchanges between each location and advances game play to the next day. To manage the mismatch in time required for different teams to complete their tasks, we require students to use the sophisticated history feature of the software (not shown) to conduct analysis of historical demand patterns of the different products by different customers. The screens where students input their daily decisions feature both graphical and tabular representations of information, drag and drop decision making, and even an expert system to completely automate the decision making. Note the "Suggest (All Products)" in the lower right corner of the screen in Figure 3 to see how to invoke the expert system. We warn the students that the expert system employs some of the same naïve rules we have seen implemented in industry and only require them to use the system if they are taking too long to complete their activities.

Game play took place in the ESD Data Analytics Lab using 21 networked computers (Figure 4) with extensive support from ESD staff, Ang Chee Kiat and Lim Lee Chen. Students were required to capture screenshots of unusual situations and submit them through eDimension. We collected the student observations and ran a debriefing session in the following lecture period. This was an entertaining and eye-opening review of the startling things that can happen in supply chains. Some of the phenomena, such as machine breakdowns are random events supplied by the software, but other crises, such as excessive orders, come about from the actions of other team members. On the other hand, we witnessed students anticipating some of the lessons of the course and attempting to override the mechanisms of the traditional MRP system to improve performance. Overall, this experience achieves the objective of engaging students in the problems faced by the NOVA Corporation and revealing abundant opportunities for system improvement.

"One of the main purposes of this game experience is to reveal the shortcomings in this traditional approach."

The NOVA cases and software are the result of multi-million dollar investments by supporting corporations and two decades of development by Professors Jack Muckstadt (Cornell), Dennis Severance (Michigan), and David Murray (William and Mary). We appreciate their generosity in sharing these materials with us at no cost.

THE IMPLEMENTATION CHALLENGE AND INITIAL RESULTS

The chief challenge we faced in implementing the NOVA experience at SUTD was in compressing the experience into six weeks (it is designed to be a full-semester course) and scaling the workload for the students to be manageable but still serve the educational goals of the course. The students were required to conduct simulation experiments with software we provided and use the results of these experiments to form a value proposition of the benefits of implementing the ideas presented in the course. We also had them analyze market data for the NOVA company and use this to articulate strategic goals for the corporation.

We were excited to see that in both case studies students have demonstrated their capability to design and manage supply chains in a more comprehensive and systematic way rather than focusing on solving only a part of the problem. For example, in the analysis of the market data for NOVA, though the students were required to analyze only regional data, many of them took the initiative to explore the worldwide conditions in order to ensure that regional recommendations would not conflict with a global optimization objective. Also, in the collaboration case study, in addition to estimating the value of collaboration, students have also made a number of proposals to reduce the overall operating cost of NOVA using the data provided, such as applying the so-called "No B/C policy" to redesign the inventory management policy. With these two group exercises as well as two more analytical homework exercises, we believe we have covered the essence of the full-semester Cornell course.

Student feedback from this portion of the course is quite positive (4.0 out of 5.0 on the midterm survey) with the major suggestion being to increase the content and difficulty level. We had erred on the side of simplifying the course too much. That will be easy to correct. We can report a successful execution of all the experiential learning components we had hoped to implement. This course is on track to becoming another unique feature of an SUTD ESD education in Singapore.

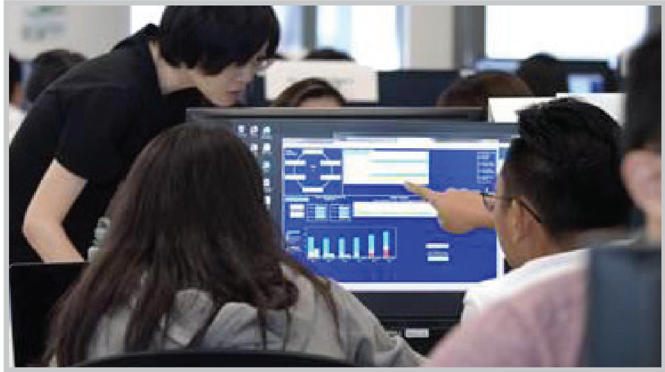

Figure 4. NOVA Gameplay in Data Analytics Lab

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ABOUT THE AUTHORS

Professor Peter Jackson *(left)* joined SUTD as Head of the Engineering Systems and Design (ESD) pillar after an illustrious 37-year career at the prestigious Cornell University. Prof Jackson has tirelessly worked to refine ESD's core curriculum to ensure students pick up the right skills. He is a celebrated instructor of industrial engineering and the creator of dozens of experiential learning games and tools.

Dr. Ying Xu *(right)* is an Assistant Professor for Engineering Systems and Design (ESD). Ying Xu received her Ph.D. in operations management at Carnegie Mellon University. She teaches freshmore in Modelling System World and ESD course for Supply Chain Digitalization and Design.

DESIGN METHOD TO SOLVE HEALTHCARE CHALLENGES IN THE COMMUNITY

DR. DAWN KOH, ENGINEERING PRODUCT DEVELOPMENT (EPD)

In the SUTD's Global Health Technologies (GHT) elective course, students get to learn about the current state of global health challenges and how technologies are used to solve them. Guest lectures, panel discussions and organized field trip also allowed students to have a first-hand experience to the industry and how they are solving global health issues. In this applied elective, final-year engineering SUTD students from the EPD, ISTD and ESD pillars also get a chance to work in a group project that focuses on real-life problems from industry partner St. Andrew Community Hospital (SACH). With the pressing need of an ageing society in Singapore, one of the core focus for the student projects is finding healthcare solutions for the elderly in Singapore. Since 2017, I have collaborated with SACH, so that students will have the opportunity to work directly with healthcare practitioners and elderly patients to understand the needs of the end-users directly. Through applying design thinking method and technologies taught in the course, students are able to thoughtfully design many innovative equipment, learning tools and devices to solve these healthcare challenges. This article will describe the pedagogy used in this course (14-week) that enabled them to do so.

Growth in the number of older person (aged 60 years or over) is a global phenomenon. From 2017-2050, virtually every country in the world will experience a substantial increase in the size of this specific age group. The increase is driven by reduction in fertility and improvement in survival (World population Ageing, 2017). It was also found that older Singaporeans (60-74 years) are ageing more successfully than their counterparts in other countries (Subramanian et al., 2019). Hence, this pose both opportunities and challenges for countries. In the GHT course, the theme for the projects is on healthcare solutions for elderly.

THE BIODESIGN INNOVATION PROCESS

The Biodesign Innovation process is a comprehensive roadmap for identifying, inventing and implementing new medical devices, diagnostics and other technologies that intends to create value for healthcare stakeholders (York et al., 2015). It is made up of three main stages: IDENTIFY, INVENT and IMPLEMENT (Figure 1).

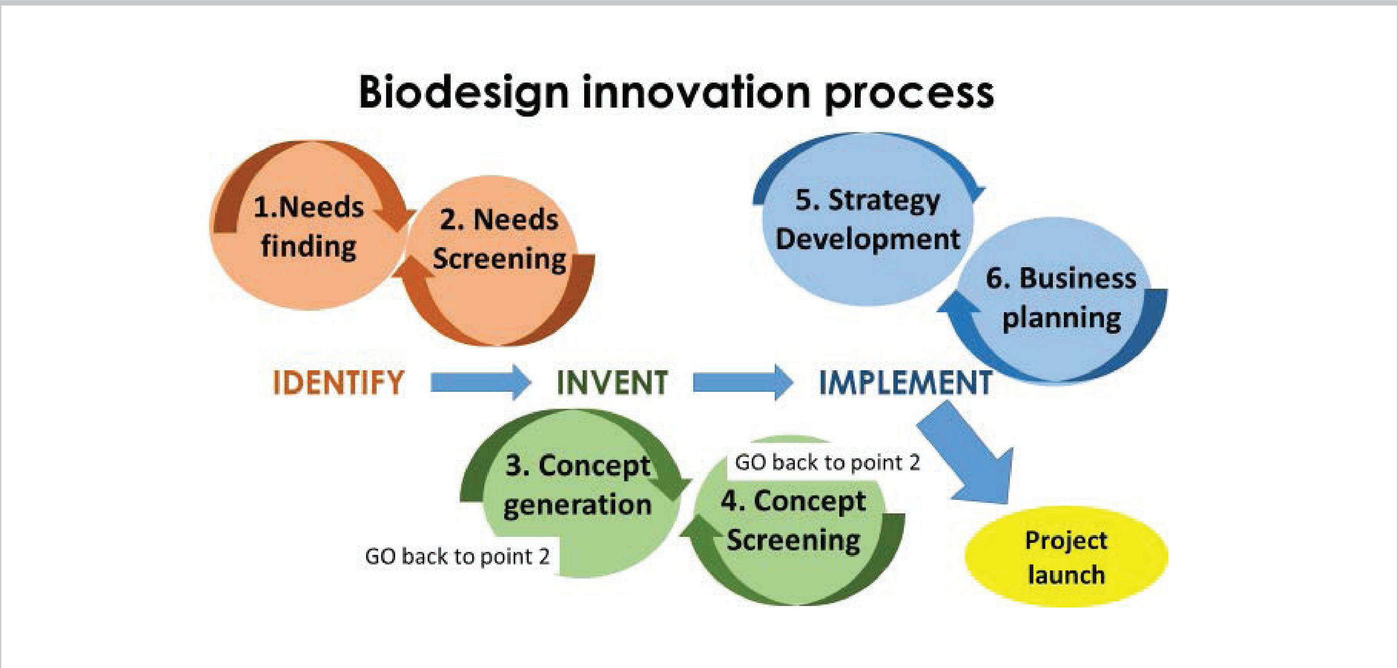


Figure 1. Biodesign innovation process started in Stanford for medical technology innovators. This technique was taught and applied in student projects in GHT course.

During the GHT course, we focused on the IDENTIFY and INVENT phases. The two phases have been modified into 3 phases for use in GHT elective: Phase I: needs screening, Phase II, concept generation and Phase III: prototypes and user testing (Figure 2).

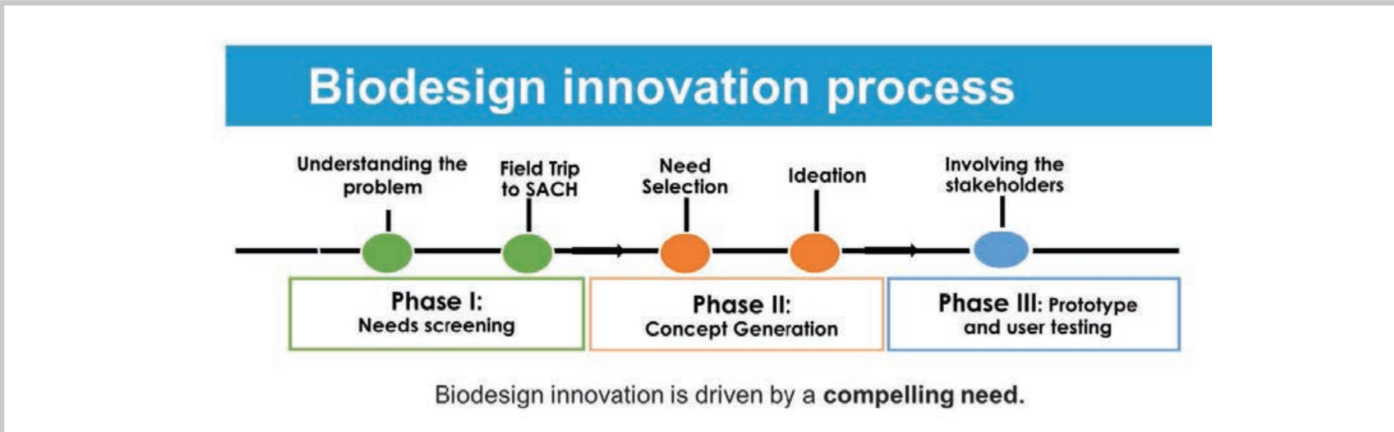


Figure 2. Modified Biodesign innovation process used in GHT course.

Figure 3. Field trip to SACH (week 3) to experience first-hand observation in a sub-acute hospital (SACH) in caring for elderly.

Phase I - Needs screening: The aim of this phase is to gather and screen a number of unmet medical needs and subsequent narrow the list down to the promising need based on information about the key clinical, stakeholder and market research. The output is a very concise needs specification document that frame the opportunities for the problem with consideration of the team's abilities. The "mantra" of this Biodesign technique is that a well-characterized need is the DNA of a good invention. Hence, in GHT course, more focus is placed on needs finding and screening. There are 5 mini-lectures: needs exploration, need statement development, disease state fundamentals, existing solutions and both stakeholders and market analyses. At the start of the course, SACH therapists will propose a few need statements for the students to choose. In week 3, an organized field trip (Figure 3) to SACH allowed the students to experience and understand the proposed problems first-hand. In some cases, the problem was demonstrated in the hospital setting. At the same time, students clarified the problem areas with the respective therapists and nurses. After the field trip, students selected their interested project and groups will be formed based on their interest. In the following 4-5 weeks (Figure 4), the student group validated this need statement through their interactions with therapists, patients and end-users by conducting interviews, background research and observation in the hospital.

Week	Lesson/Activity
3	Field trip to SACH
4-13	Group work to develop and implement solution at SACH
7	Interaction with patients, therapists (end-users)
8	**Deliverable 1:** Need statement and 3 possible solutions (presentation)
9	Age sensitizatioin workshop
10	**Deliverable 2:** Testing plan and prototypes
13	**Deliverable 3:** Poster, prototype, exhibition and final report

Figure 4. Student project time-line and deliverables

During the recess week (Week 7), students spent about two hours in the hospital to conduct interviews and observation to validate their need statement.

Deliverable 1: Group presentation and report to both SACH mentors and SUTD course lead, the student group presented their 3 best validated need statements and 3 possible solutions that they would likely achieve by the end of the course. At the same time, they also submited needs specification document. The needs specification document is a detailed but succinct stand-alone document that (1) presents the need statement (2) summarize the data gathered through needs screening process (3) outlines the needs criteria of any solution must address in order to satisfy the needs. They must be organized into "must-haves" and "nice-to-haves". In addition, to equip students to better understand their target users (i.e. elderly), I arranged for an "Age sensitization" workshop: In this workshop, students learned about some of the daily challenges faced by elderly. Through simple role-play, the students will experience what is like to have failing eye-sight and aching joints while carrying out simple daily tasks. Hence, both workshop and the need specification document would be useful for the next phase of the project- concept generation.

Phases II and III: The main purpose is to explore solutions to one or two defined needs by using various creative ideation techniques, prototyping and testing methods to filter the best solutions to fit the needs of all stakeholders. Throughout the entire duration of these two phases, both SACH mentors and I will meet with the student groups weekly for consultation and progress updates. The purpose of the consultation sessions is to ensure a timely delivery of their final prototype and to address any issues the team may encounter during the week.

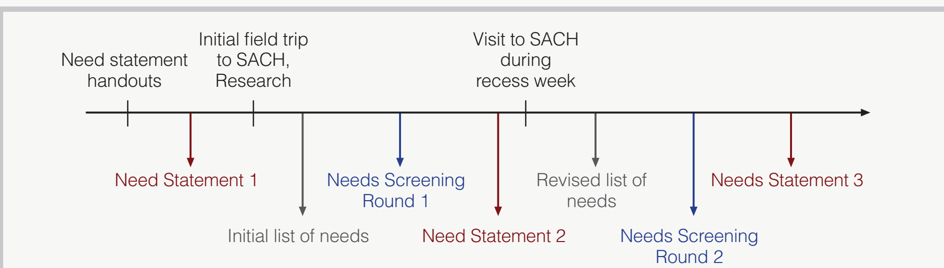
Deliverable 2: Testing plan and prototype. Students described their testing plan for various features in their prototype also with their target user. They listed down the various features for testing and predicted what results they will get and a rough timeline for the actual testing. The report should document their prototype evolution with each testing done and the results that were obtained.

Deliverable 3: Final prototype and course exhibition. From the results obtained from their user and feature testing, the students proceeded to work on their final prototype. The findings of their entire learning journey were documented in a final report and poster. A 5-minute video also described how their prototype helped to solve the hospital needs. The course culminated with a 2-day public exhibition for healthcare providers and SUTD community.

The next section contains excerpts from a final group report from students of the GRIP project. The team consists of Janelle Ong (EPD), Victor Lee (ISTD) and Law Jia Li (ISTD) and Shadman Ahmed (exchange student) that describes their learning journey (especially the needs screening and selection process) in this course.

Background of need in the hospital: "Recovering stroke patients often lack the grip strength to hold onto the handles of rehabilitation machines. The use of these rehabilitation machines during rehab sessions are very crucial to these patients, hence the desire for occupational therapists in SACH to find efficient methods of securing the patients' hands. The current method that the occupation therapist uses is the crepe bandage. Although wrapping the crepe bandage around the patients' hands is secure, it is equally time consuming given the short therapy sessions of about one hour and high patient to therapist ratio of 15:1. Therefore, our team proposes "GRIP", a glove designed to effectively secure the hands of upper limb stroke patients with weak grip strength onto handles of various exercise equipment, while maintaining proper grip form allowing patients to regain their upper limb strength. The user testing with the prototypes have yielded good results and feedback from the therapist."

Needs evolution: As a summary, the 2 diagrams below depict the evolution of needs that we have gone through.



Comparison of Must:

- Our must haves and good to haves can be seen in Table 7.

Must Haves	Good to Haves
• Does not compromise safety of patients when in use • Comfortable to use • Should be compatible with both left and right hands • Should be compatible with patients of different hand sizes • Does not increase net healthcare expenses to system • Able to be cleaned and ready for use within 4 hours	• Allows for removal and storage in less than 1 min • Able to be safely and effectively utilised for 5 years • Simple training to allow for rapid adoption

Table 7: Must Haves and Good to Haves

Evolution of prototypes

Final prototype

COMMENTS RECEIVED FROM VARIOUS STAKEHOLDERS:

Students from GRIP project

It has been rewarding to see our prototype benefiting the patients' at SACH, it proved to us that we could make a meaningful difference through our designs. Working with the therapists at SACH has been very eye-opening. As healthcare professionals, they approach the same problem from a very different perspective from us, hence it was great that we had the opportunity to learn from them and learn communicating with them. Their insights have been invaluable to the outcome of our project. Additionally, the hands on component of the project gave us a better understanding of the bio design process and allowed us to actually put our learning into practice. It has shown us how repeated cycles of user testing and design iterations contributed to the creation of our final prototype.

Hospital mentor Ms. Loh Wei Chin
Principal Occupational Therapist and Manager, Day Rehabilitation Centre @ SACH

This is my first time working with the SUTD lecturer and students on the project. I must say that I can see the efforts put in by the students during the presentation of products, field trip and their final product. The end product is quite impressive.

Hospital mentor Ms. Anna Lee
Principal Occupational Therapist and Senior Manager, Inpatient Therapy Services @ SACH

In a span of two months from field trips, attachment to project's mentors to understand deeper the needs of the end users, mid-term project review to the exhibition of the final product, the SUTD students have come up with prototypes that are useful, meaningful and purposeful to our patients. For the past two years, I saw a great improvement in the students' design thinking and enthusiasm to create products that tailored to the very needs of our elderly patients. Best of all, we can keep the products. Hence, I truly saw the collaboration a win-win situation between SACH and SUTD. And totally agree it's a great way to nurture our youth to improve the care of our elderly through such collaboration.

Hospital mentor Mr. Galvin Tan
Occupational Therapist, Inpatient Therapy Services @ SACH

Initially (the students) were a little apprehensive as it could have been their first time engaging with an elderly. They required OTs (occuptational therapist) to help facilitate the asking of questions to the elderly. However after facilitation by the OTs, subsequently, they started to initiate and ask the elderly more questions on their own. After interaction with the patients, (the students) were also able to fine-tune their solutions to meet patients' needs (i.e. address stability of the clothes hanger equipment, ensuring comfort of the product when patient uses the item, making it more challenging and more attuned to real-life scenarios).

EPD Head of Pillar Prof Chua Chee Kai

Healthcare is one of the key growth areas for SUTD. Global Health Technologies led by Dr. Dawn Koh has successfully incorporate design thinking to advance innovation in healthcare that is both patient-centric and cost-effective. External collaboration with industry partner (St. Andrew's Community hospital) allowed students a chance to use more hands-on approach to work on real-world problems and solve them with outstanding products.

The collaboration with our industry partner (SACH) was so well-received that we had a joint media released in June 2019.

Joint media release by SACH and SUTD:
Channel 8 news: *Shaun Phua (EPD) SUTD student, and Anna Lee, SACH principal occupational therapist.*
The Straits Times: *SUTD students Lu Wan Yun (EPD) and Ivan Tang (ESD).*

Here are some pointers to take note when working on collaboration projects with industry partners:

- **Framing the question well:** Faculty members have to be able to narrow the scope of the project to a manageable size (in my case, 2 month period). Also, be realistic about their final solution given the time frame.
- **Determine the right mix of skills required by the project.** Allow the students to choose their interested project and also check the required skills needed to complete the project.
- **Encourage open communication with all stakeholders (e.g. therapists, patients, students and course instructors).** I would ask the students to summarize the weekly consultation meetings with me and it will be shared with SACH mentors via email. This is to ensure that expectations on project deliverables are clearly aligned for all mentors and students.
- **Equal contribution of each member in the team.** As in all group projects, I have 3 rounds of peer evaluation (throughout the project duration) to determine contribution of each member.

In conclusion, the use of this design method to discover and solve healthcare problems in the hospital has resulted in several useful products for the community. Through working with real-life problems presented by SACH, students were able to readily apply this design thinking method.

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Dr. Dawn Koh is a Senior Lecturer in the Science and Math Cluster, with joint affiliation to Engineering Product Design (EPD). She is also the course lead of the Global Health Technologies (GHT) elective at SUTD. She received the SUTD Teaching Excellence Award in 2018.

CONTOURS OF THE DOUBLE DESIGN METHOD

MS. CHRISTINE YOGIAMAN, ARCHITECTURE AND SUSTAINABLE DESIGN (ASD)

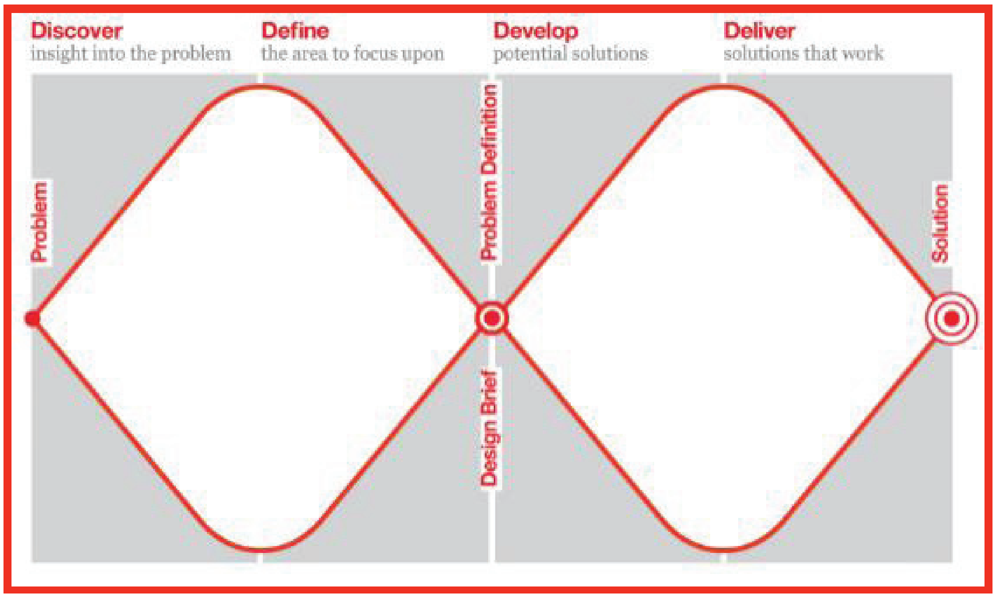


Figure 1. Design Council's published Double Diamond design model: Dividing the process into four distinct phases – Discover, Define, Develop and Deliver.

The double diamond design model was a visualization developed in 2005 by Design Council, a UK independent organization established since 1944 to empower the country's design economy. The model was a consolidated finding from a long-term qualitative study of the contemporary design process practiced across eleven world-leading companies, including Alessi, LEGO, Microsoft, Virgin Atlantic Airways, Starbucks, etc. The finding was striking, as it defined a common approach that design practices across disciplines share. It was also a provocative reference for the course coordinators of, Introduction to Design, a signature first year foundation design course. The course envisioned an inclusive, inter-disciplinary design education and is unique to Singapore University of Technology and Design pedagogy.

The term "double diamond" referred to the distinctive shape outlined by the quantity of ideas, intentions or considerations that increased when a designer was exploring, followed by the act of selection when the quantity of ideas was narrowed. The finding demonstrated that this increase or divergence, and decrease or convergence of ideas, happened twice in the whole design process. The first "diamond" described the Discover and Define design phases, and the second happened during the Develop and Deliver design phases.

A quick overview of existing design courses within the course coordinator's individual disciplines of Engineering and Architecture, revealed tendencies for design courses to begin at the end of the "Define" phase, where the problem and the perimeter of success is pre-defined at the start of the course. Even in a seemingly open-ended design course, the course often retained the structure of starting at the "Define" phase; by giving an overview of the complex interdependence variables that contributed to the issue at hand as the pre-determined 'definition' and call for students to act on opportunities in any way within this boundary. This disciplinary specific design course approach was effective and paramount, as faculty take into consideration the limited time a course has at its disposal to impart ways of working within deep domain specific knowledge.

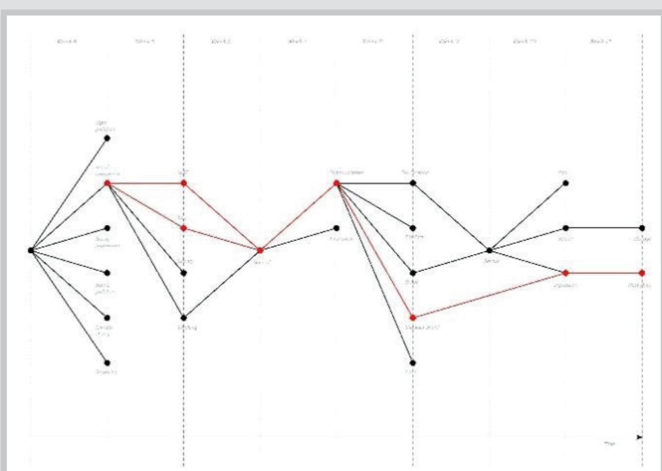
In many ways, the Introduction to Design course did not share the same constraint. It was conceived as a shared foundation design course, run at the first year of the student's university education prior to their discipline specific training. In this regard, the course had a freedom to experiment with implementing the Double Diamond design model within educational setting. The translation of this industry and design-practice based design process to students' design learning experience was not without adjustments and certain distortion.

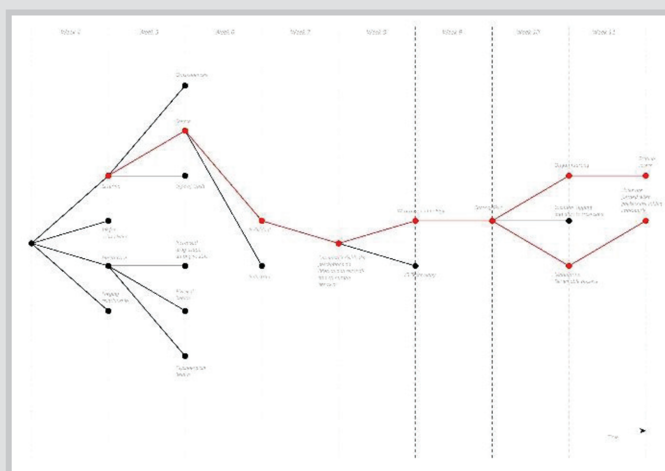
The 13 semester weeks were divided into four distinct phases of the Double Diamond model, and with repetition of the course over four years, the duration and phase distinctions were altered based on feedback and the coordinator's desire to hone the dynamics of interactive learning. In its most recent year's rendition, the 13 weeks was divided in this way: weeks 1-3 dedicated to a Pre-Discovery conditioning period; week 3-5 for the consolidation of Discovery and Define phase; week 6-10 dedicated to Develop phase, and week 11-13 to the final Deliver phase. In the same year, seven teams in one of the course's classes were asked to self-record their design process from the start of the Discovery at week 4 to the beginning of Deliver design phase at week 11, as an attempt to capture the inner workings of the divergence and convergence thinking stimulus that the course was orchestrating. Each week, the teams were asked to list the number of ideas they were working on, and if ideas were connected to previous week's ideas, to draw lines that represented these cognitive links. Subsequently, red colour was used to distinguish the collection of ideas that had made contributions to the final project at the end of week 13.

The patterns that emerge from these self-recordings were more intriguing than initially expected. They gave an insight to the interactions between the dynamics of the team and their ability to reciprocate the exposures to divergence and convergence thinking stimulus. A few observed distinctions could be made. Pattern A represented teams least affected by the course's stimulus. Pattern B shared similarity to pattern A, with the exception that the teams in this pattern exhibit a clarity of design direction towards the end of the documentation period that allowed for an exuberance of design advancement. Pattern C shared attributes to pattern B, with the distinction of having had many initial ideas that did not converge in any effective way. Pattern D was categorically distinct from other patterns, as the team self-initiated short intervals and series of convergence, between periods of phases, and was the quickest to react to the primary convergence motivation that came from assignment deadline asking for teams to articulate their design goal and criteria for success. A closer reading into the workings of pattern D identified that the group of ideas listed within week 5 and 7 shared close alliances that allowed for immediate and natural consolidation of intent the following week. This contrasted with the workings suggested by pattern E. This team had a robust reaction to the divergent thinking stimulus at the beginning of the Discovery phase. In the subsequent Define and Develop phase, this team sought to consolidate two ideas of diverse dimensions and enabled the team to arrive at a rich provocation that contributed to a healthy diversity at the end of Develop phase.

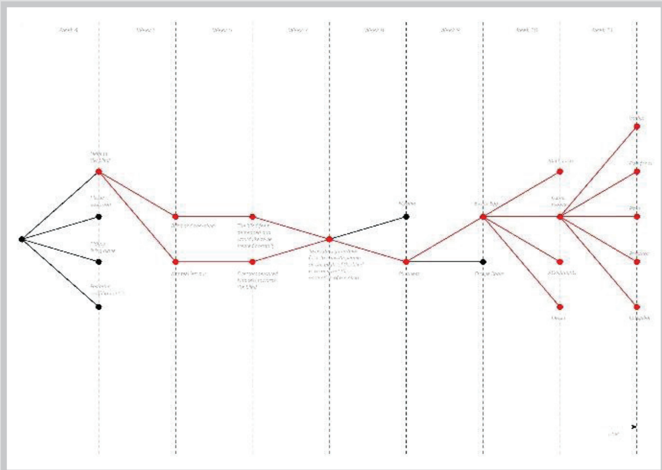
In retrospect, the collection of patterns gathered might contain much inconsistencies that arose from each team's interpretation and different self-documentation tendencies. This made the comparison between patterns and any insights and distinctions discussed above less pertinent. However, as demonstrated from the descriptions above, a faculty was able to draw reflections on the effectiveness of her cohort's design teams' reaction to the staging and timing the course materials are delivered. These recordings could become an immense resource for personal teaching reflections as team dynamics and inner workings may not be the most transparent and accessible to a faculty during the semester, especially in the context of teaching a larger number of students in a design course. With these self-recordings done across multiple cohorts, there could be a potential for a course coordinator to draw larger trends on the effectiveness delivery of his or her course to incite certain design team dynamics.

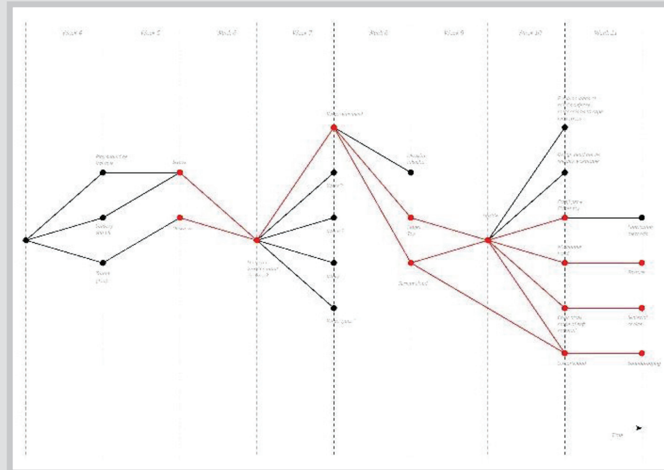
PATTERN A



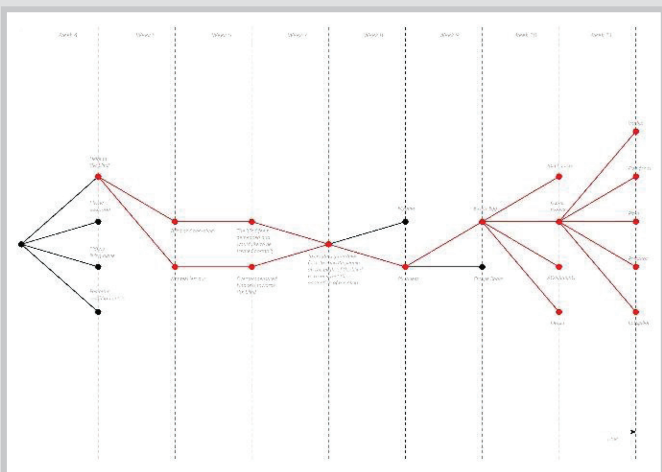


PATTERN B

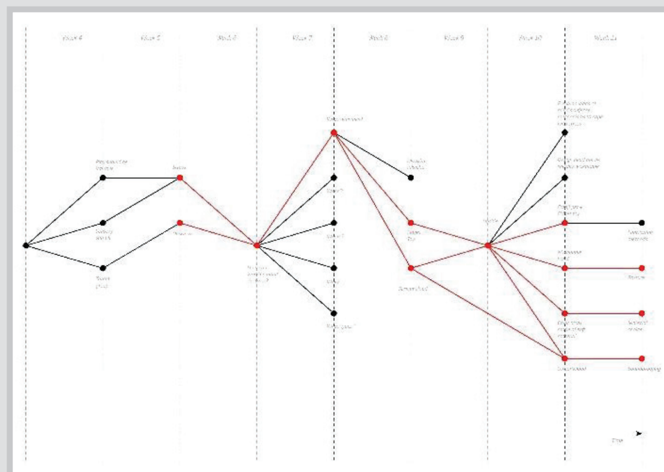




PATTERN C



PATTERN D



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AN APPROACH TO INCORPORATE EXPERIENTAL LEARNING IN MEDICAL DEVICE DESIGN AND INNOVATION COURSE

DR. SUBBURAJ KARUPPPASAMY, ENGINEERING PRODUCT DEVELOPMENT PILLAR (EPD)

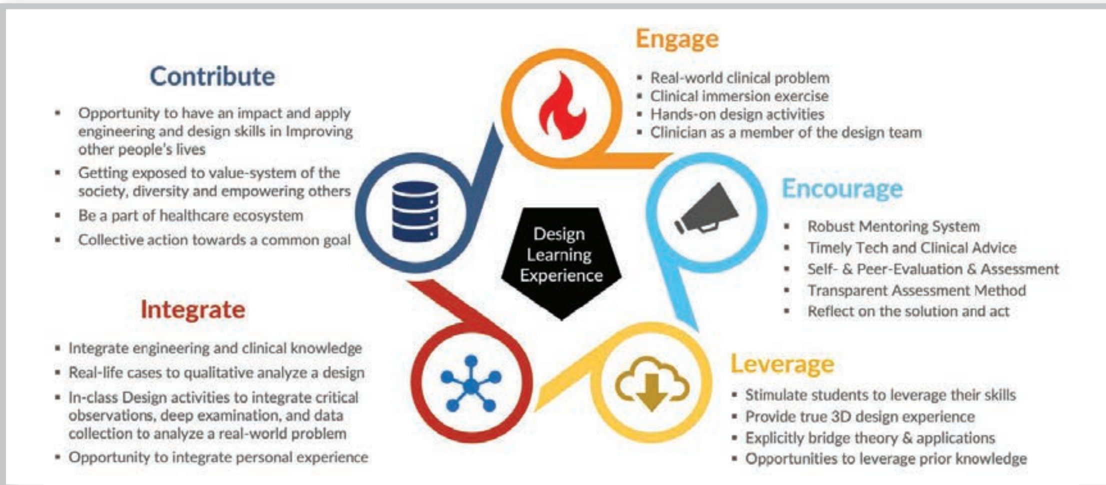


Figure 1. An Experiential Design Learning Experience Framework

The innovative design of a product determines its impact on our lives and added value. In line with SUTD's mission of nurturing 'technically-ground leaders', we must instil not only multi-disciplinary technical expertise in our students but also lead them to listen, observe, examine, question, identify, and understand current clinical problems, and then apply their technical and design skills, learned in other technical courses, to develop focused and viable solutions. Due to significant advances in science, engineering, design, technology, and manufacturing, the students must be trained to understand and exploit these capabilities to innovate healthcare products and practices. Experiential design learning process offers an avenue for students to actively experiment, experience, make mistakes, reflect, and refine with their team-based design projects and maker activities. In healthcare product design course, the experiential learning process was implemented to emphasize the following five elements during their learning journey: (1) engage, (2) encourage, (3) leverage, (4) integrate, and (5) contribute (Figure 1).

HEALTHCARE PRODUCT DESIGN

This course is structured to address real-world, industry-supported healthcare issues identified by partner healthcare providers. It is attended by the senior-year EPD undergraduate students. These students have undertaken several design courses and projects, involving functional requirements identification, ideation, prototyping, and testing, prior to this course. Clinicians pitch their identified unmet clinical needs to the students in the first class of the course highlighting primary functional requirements. Students then submit their interests via a ranked-voting system. Teams of 3-4 students are formed based on a first-come-first-serve basis by the first week. Students then work with the respective healthcare professionals while being mentored by an SUTD biomedical design faculty. Students use the design thinking process of immersing, shadowing and observing (Figure 2) to frame/reframe the design problem, develop user needs and engineering requirements, to conceive, select, design, fabricate, and demonstrate a working solution for the clinical problem by the end of the term.

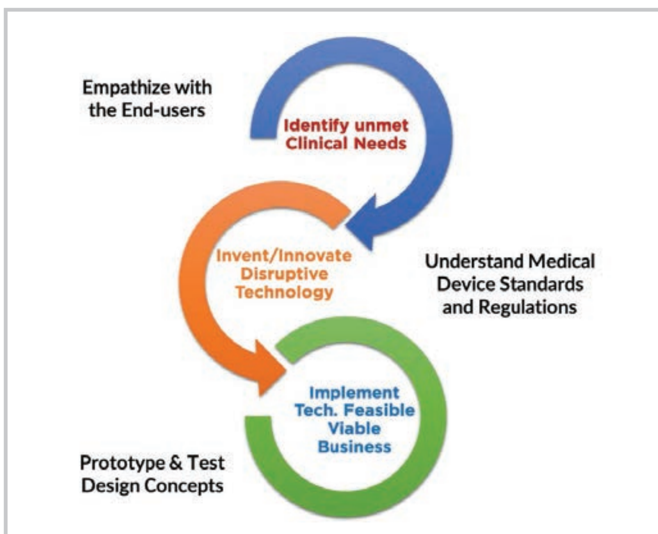


Figure 2. Overall design thinking process experienced by the students in healthcare

ENGAGE

Clinical immersion exercise makes the learning to be relevant and meaningful instead of what is learned to what is experienced. Powerful personal experience during the clinical immersion exercise and having a clinician as a member of the team to provide regular feedback on their understanding of the clinical need as well as clinical usefulness of potential design solutions at the early stage of the design process keeps the students engaged and builds motivation among them. This exercise makes them exposed to the concept of user-centric design needs, usability, technical requirements, and understanding the design constraints associated with the functional design of medical devices.

> “The course has been a truly immersive learning experience for many of us as we were exposed to clinical settings and the real needs and problems at hand. The clinical impact that each project is associated with has truly made the course a memorable learning experience in SUTD for me.”

A clear set of instructions provided to the students in the form of directed questions that may be asked during their clinical immersion exercise to the end-users (clinicians or patients) to have a clear understanding of the clinical need including, (1) physiology and biology of the disease and target population, (2) shortcomings of the current treatment protocol and technical solutions, (3) stakeholders and their level of influence and incentive, and (4) and market potential of the clinical need to worth pursuing further. Also, this exercise connects the students with what is learned to what is felt by them. Besides, mini hands-on design activities in cohort classes along the lines of points as mentioned earlier reinforces their understanding of core concepts that were taught in lectures and relate and apply them to a real-world clinical problem. However,empathizing with the end-users who face the real clinical problem is the key, which makes learning more relevant and meaningful that lead the students to be involved deeply and sustain their engagement with their design project. At the end of this exercise, students were able to reframe the clinical need based on their understanding, characterize and quantify the risks and reward, and discover insights that may lead to innovative design solutions. This process involves extended effort, mistakes, collaboration, brainstorming, reflection, and refinement.

ENCOURAGE

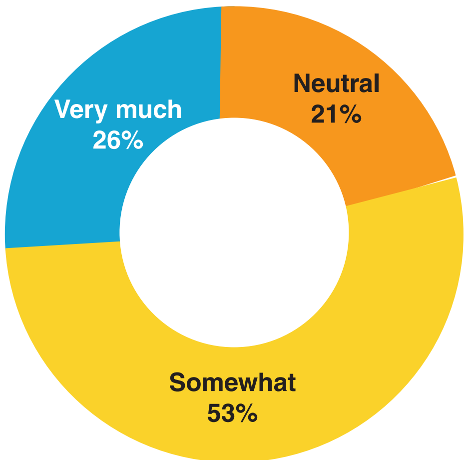
Key Points of Learning via Peer Learning and Assessment

- Understand - how to improve myself and my team's work by listening to critiques and new ideas from peers in addition to course faculties and clinical mentors
- Knowing what we can learn from others (more specific aspects)
- Realizing what I personally value or find important in a design project
- Helps to research on all project ideas while assessing them
- Get a clear idea of what to improve and opens up many opportunities to benchmark our self with the best of our peers.

Empowering students to be responsible for their learning makes the experiential learning a very personal one and encourages them to be proactive with responsibilities to achieve the desired learning outcomes of the course. A robust project-mentoring and monitoring system was implemented to monitor the student progress and project development while encouraging the exploration of their strengths and interests with their design project. This system includes, (1) Group WhatsApp including the clinician to have regular project progress update and provide just-in-time design feedback, mandatory minutes-of-meetings and action items with an assigned team member for every action item to give ownership and responsibility, (2) a team design journal that documents design history, sketches, discussion points, and actionable steps that is reviewed by the course faculty during cohort classes to encourage the students to be proactive and productive, and (3) a self-and peer-evaluation framework to have an open feedback on their team design project from their peers, make the learning process to be competitive, and benchmark themselves with respect to other teams in the cohort. These standardized but flexible knowledge exchange and documentation allow building trust and motivation that fuel a widening array of experiences during the learning process.

As discussed above, a version of peer evaluation and assessment framework was developed in collaboration with Nachamma Sockalingam of Learning Science Lab at SUTD to encourage the students to have a candid discussion and brainstorming and provide constructive feedback during design review sessions. A dedicated 30 mins session was allocated to explain the Rubric, answering any questions that may have from the students on the evaluation criteria, and what to cover during the project presentation and demonstration to assess a criterion in it. Then, a feedback page for each project on eDimension portal was enabled to let other teams provide qualitative as well as direct feedback on the project instead of just a quantitative assessment from the faculty. The framework was piloted to observe (1) how this framework engages all students in the cohort and encourage them to provide constructive feedback to their peers and (2) how students would appreciate the importance of peer feedback and self-evaluate after evaluating all other teams. Also, the framework was designed to let students reflect on their experience to build metacognition.

From this pilot exercise (Figure 3), the following conclusions have been drawn that would pave the way in designing assessment methods for this course in the future: (1) transparency is key, no matter what type of assessment is being used (students should know-how, what, and why they are being assessed in a particular way to reduce some of their anxiety and promote better interest and understanding), (2) rubrics should outline expectations clearly and with sufficient detail, but they should not feel restrictive (should offer enough flexibility in assessing qualities that vary between projects and develop over time based on students' feedback and input), and (3) peer-assessment is an untapped resource due to some associated implementation difficulties, however if it is implemented thoughtfully with appropriate guidance for students, it is an effective assessment tool especially in multi-disciplinary design-centric projects.



"To what extent has the Peer Evaluation and Feedback activity made you feel more involved in and helped you focus on the learning process (design review, team dynamics, brainstorming, and communication)?

	Not at all	Not really	Neutral	Some what	Very much
Gap in understanding	-	5%	30%	40%	25%
Others' Perspectives	-	10%	15%	50%	25%
Weakness	-	10%	10%	60%	20%
Prototyping	-	-	10%	50%	40%
Design process	-	-	-	75%	25%
Brainstorming	-	-	20%	50%	30%
Design Reviews	-	-	5%	65%	30%
Pitching	-	-	30%	45%	25%

"To what extent has the Peer Evaluation and Feedback activity made you feel more involved in and helped you focus on the learning process (design review, team dynamics, brainstorming, and communication)?"

Figure 3. Students' response to Peer Evaluation and Feedback

LEVERAGE

Students are often motivated when they see useful connections between their classroom learning, prior knowledge and experiences, and future work in and out of the classroom. In this course, when clinicians pitched their clinical need for review before the course begins, the course faculty reviews those needs and assessed in keeping the criteria mentioned above in mind to stimulate students to leverage and apply their skills and knowledge to solve a real-world clinical problem (Figure 4). Students are also highly motivated to build on experience toward a more significant impact and craft a change-maker story with their course project for their design portfolio in this advanced design elective course.

Medical device design and development requires inputs from multiple engineering disciplines, including bio-medical, biotechnology, chemical, communications, computing, sensing, design, ergonomics, electrical, electronics, materials, mechanical, manufacturing, and software. Experiential learning activities, including (1) in-class design activities on a simple design project that can be done in 2.5 hours of time; assignments based on the design thinking methods that the students have learned in earlier terms courses with some overview and guidelines and (2) explicitly relating core technical concepts learned across different terms and academic years using well-defined case studies, help them leverage their own vivid experience to bridge from what they already know from previous year or term courses to the new material that is being taught, in terms of both content and skills. The convergence of different disciplines and collaborative skills has opened a new door for many healthcare applications. Figure 5 shows representative design-centric multi-disciplinary course projects where students have leveraged their learned engineering, design, and collaborative project management skills from Term 1 to 7 to produce an innovative design solution.

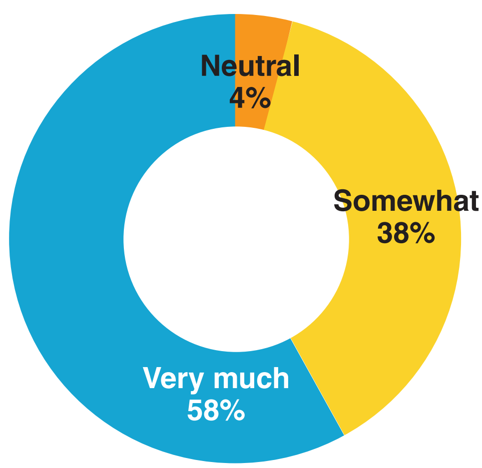


Figure 4. Students' response to "How much do you think your design, engineering, and project management skills from previous term courses including 3.007 and 30.007 courses helped you with your medical device design project in 30.123 Course?"

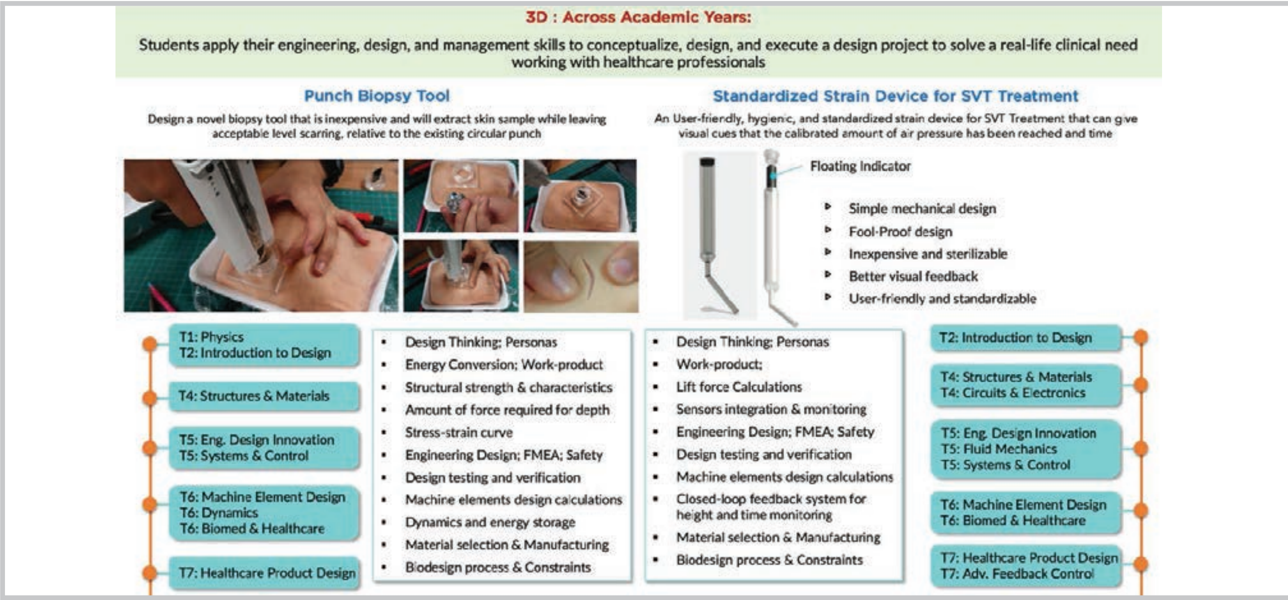


Figure 5. Representative 3D design-centric multi-disciplinary course projects where students have leveraged their learned engineering, design, and collaborative project management skills to produce an innovative design solution to solve a real-life unmet clinical need.

INTEGRATE

Students have different sources of motivations and have different technical expertise and experience with respect to their track choices in the pillar year and industry internships they have undergone in their sophomore and junior years. Lessons through the use of stories (from real-life experience or made-up ones) predate current educational theory to teach students to define core scientific as well as social concepts that they do not understand easily. The use of business cases, surgical case reports with video recordings, radiographic images well-defined lesions, and case-laws as a learning tool is a generic extension of century-old method of teaching adult soldiers how to understand complex military planning and execution concepts by understanding the basic elements of a military operations order using prior wars or battles as case-studies. A case study is a learning method that involves critical observations, in-depth interviews, gathering in-depth information from different sources, a detailed review of collected documents, and integrating with the performers' own experience, thoughts, and explanations.

In this course, case studies on clinically used medical devices were integrated as a part of the learning process to enable students to perform an in-depth examination through the use of "how, what, and why" questions, including (1) how was this need identified in clinical settings, (2) what are the user requirements this device fulfils, (3) what are the design constraints in terms of users' as well as physiological perspective, (4) how is it used in a clinical settings, (5) chronological design variations of the device from the moment it was introduced for clinical use, (6) what are the other solutions available for the same clinical need, (7) what kind of certification process the device underwent, (8) what are the testing protocol followed for FDA/CE certifications, (9) what is the business model of the device, and (10) envisage how advances in technologies and user preferences would affect the current design of the device. This case study exercise is carried out as a team, where different expertise, experience, viewpoints create a platform that encourages brainstorming, peer learning, consensus, and collaboration (Figure 6). Then each team presents their case study to their peers and faculty in the classroom with a constraint that rest of the teams in the class must ask at least two questions to the presenting team. As we all know, experiential learning is an integrated process with the chance to go deep in learning core concepts and apply to answer relevant questions in the world.

This exercise addresses the issue of fear of medical device design by providing them a design journey of an existing device to understand the complexity and the need for design engagement, problem-solving attitude, and collaborative effort of a multidisciplinary team to bring a medical device from a concept to market. Besides, this experiential learning exercise reverts from the "faculty to student model" to a "learning facilitator and student" model, where the student makes design choices using experiences, abstract principles, generalizations, and analysis, in short, different dimensions of theoretical knowledge to formulate concepts that integrate their observations in those case-studies with logical theories.

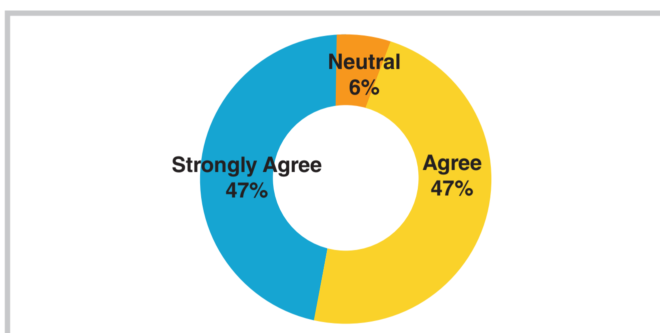


Figure 6. Case-study exercise provided an experience to analyze a design problem from a multi-factorial stakeholders' perspective, including clinical, physiological, engineering, design, and market constraints.

CONTRIBUTE

Design thinking combines a deep understanding of and empathy with the end-users, together with contextual creativity and a rational approach to synthesizing their experiences and solutions. It is the secret sauce that makes innovation strategic, and make it really matter, while science, methods project management make it possible.

To make an innovative product that leads to real contributions to the society, cross-disciplinary, collaboration, and project management skills, as well as initiative and persistence, are required. To meaningfully contribute now and in the future to the society, the students must experience healthcare design challenges that tackle four critical factors, namely availability, affordability, reliability, and suitability considering the significant shift in the market from the developed world to developing world.

A design activity was framed to enable students to understand and experience the broader business context of medical device development by asking the following four critical questions:

(a) Is there a significant proven local need?
This criterion is to enable a better articulation of the clinical problem and easier testing of the innovative design solution at the early stage of the design, development, and testing.

(b) Does it have innovation potential and value proposition?
In the current market scenario, one should not waste time, effort, money, and resources unless it can lead to a breakthrough technology at least 4-5 times the efficacy (better outcome), efficiency (shorter time / lesser effort), and economy (reduced cost to the enduser).

(c) What kind of a committed team needed to take it forward?
Involvement of key stakeholders, especially expert clinicians throughout the product lifecycle, including idea generation, design feedback, proof-of-concept, evaluation of detailed design and prototypes, and clinical trials and marketing.

(d) What kind of relevant technical capabilities and facilities to develop the device?
This criterion is an important one: the manufacturability of the device. Students tend to take easy routes like 3D printing, laser cutting, and water jetting to get the early stage prototype. However, the designer should consider how the end-product would be manufactured in pilot batch production, inspection, testing, sterilization, and packaging to avoid significant late-stage design change.

In addition, this design activity also teach the students to analyze their design in using strengths to take advantage of opportunities (opportunity-strength strategy), using opportunities to minimize weaknesses (opportunity-weakness strategy), using strengths to minimize threats (threat-strength strategy), and using threats and weaknesses to offset each other (threat-weakness strategy) by performing SWOT analysis. Students also learn to work and communicate effectively in multidisciplinary teams to tackle real-world clinical problems. Students recognize the value and importance of taking collective action toward a common goal, valuing others in the team, building relationships in the healthcare community, getting exposed to diversity and adversity, having an impact, improving other peoples' lives, and empowering others
while advancing the science and technology through their design project. In this sense, the activity instills not only technical expertise in students but also lead them to examine and question the goals and value-system of the society they are being prepared to build.

SUMMARY

In summary, health is the topmost sustainable development goal set by the UN to achieve by 2030. There is an increasing reliance on medical devices and equipment to diagnose and treat diseases, injuries, and disabilities well in time. Many doctors, engineers, and patients are fascinated by medical devices. However, the design, development, testing standards and protocol, and safety certifications of these devices are relatively new and complex and requires close collaboration between experts from different technical domains to minimize health risks. Thus, there is a need for such multi-disciplinary design engineers who can understand the clinical need better and frame the need into an engineering problem to develop an innovative design solution within the constraints offered by various stakeholders and market. The framework that has been developed and implemented in this course to provide opportunities for the students to (1) experience the bio-design process and clinical immersion to have a first-hand understanding of the real-life clinical need, (2) apply what they have learned and draw on new and old knowledge to demonstrate their understanding through a design project, (3) get assessed based on their performance through demonstration, observation, collaboration, fieldwork, and reflection, (4) learn from past successful and failed cases by performing an in-depth examination through the use of "how, what, and why" questions, and (5) make a meaningful contributions and value additions to the society by developing a marketable innovative design solution for an immediate clinical need, not a make-believe one. Implementation of this experiential design learning framework leads to superior performance and enjoyable learning experience for the students. Therefore, providing students with more experience-based learning combined with real-life need-based design opportunities leads to performance enhancement and skills improvement.

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ENSURING SECURE PROGRAMMING EXAMS FOR "DIGITAL WORLD"

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University courses have traditionally been assessed by closed examinations: pen and paper, separated desks, a clock counting down, and invigilators pacing the room. This format has survived the test of time because it is simple for instructors to administer with well-established logistics, but most importantly, because it is run in a highly controlled environment in which the possibility of plagiarism can be minimised.

In a modern university curriculum, however, this style of assessment is completely misaligned from the learning objectives and pedagogies of several courses. In a computer programming course, for example, students learn how to program by interacting with a language's compiler or interpreter – trial and error, testing, debugging, and looking things up in a manual are all part of the programming experience, regardless of student ability. A traditional closed exam for such a course is limited to testing concepts, or the ability to 'code' on pen and paper, forcing instructors to simplify the questions and forcing students to train for the exam. Using the environments that students learnt on (e.g. programming environments on own laptops) is, unfortunately, extremely difficult to control for plagiarism or costly to set up. While coursework components can alleviate this problem, retaining a final exam of some kind remains common practice, given the stronger guarantees provided by these examination environments.

In this article, we discuss the use of "lockdown browsers" as a compromise solution, describing how they facilitated a controlled interactive programming environment for the closed exams of Digital World, an introductory programming course in the freshmore year at SUTD. We reflect on our experience of designing and implementing this new setup, in the hope that our lessons can help other instructors who seek to examine on unconventional platforms in controlled settings. Among our conclusions is that technology alone is not sufficient, and that policy and human factors are equally important to consider.

RELATED WORK

Instructors in general are aware of the need to align their assessment, learning objectives, and pedagogy (Biggs, 1996). Many studies report benefits of using practical exams for programming. A practical exam allows students to demonstrate their programming skills in a setting that is close to how they typically program day-to-day (Bennedsen, 2006). The grading of student answers can often be carried out by automated assessment tools, thus enabling feedback to be provided in a shorter time compared to manual marking. Students are positive about having access to a compiler, as it enables code to be tested and syntax errors to be caught (Stephenson, 2018). Finally, having practical exams allows data on students' answers to be collected, enabling further analysis of errors that students make (English, 2002).

Dedicated computer laboratories require significant investment, and are not practical for exams with large numbers of students. Running exams on students' own laptops, commonly termed as "bring-your-own-device electronic exams" or "BYOD e-exams", is another solution. Hillier and Fluck (2017) describe how a secure and standard operating system environment can be provided by giving each student a Linux USB stick to boot up their computer. Riberio and Amaral (2018) required students to install the open source Safe Exam Browser (2019) software to restrict network access in their multiple-choice exam.

In the rest of this article, we will describe our efforts to provide students programming assessments in which they can bring their own devices, but at the same time, are secure enough that cases of cheating can be reduced or eliminated. We also discuss factors beyond the technology itself that are critical to running a smooth exam, such as examination protocols and policies, emergency mitigation plans, technical support teams, and invigilators. We first begin by considering the context of our education system at SUTD and how the programming assessment of "Digital World" was previously conducted. We discuss how we then implemented and conducted the online practical exam for programming, and reflect upon some of our key learning points.

CONTEXT

Digital World is an SUTD freshmore course which introduces computational thinking and programming using Python. In this course, students are assessed individually using a mid-term and final exam, together contributing 50% of their final mark. Both exams are split into two parts: the first part uses short traditional-style questions to test concepts, whereas the second part uses programming exercises to test that students can put those concepts into practice. Given the large number of students and limited lab space, the latter part required a BYOD solution, which has evolved over the course iterations.

In the very first mid-term exam of DW in 2013, students were allowed unrestricted use of the internet, similar to Stephenson (2018). However, despite the presence of invigilators, it also facilitated some cheating, with students sharing solutions easily using file sharing platforms. This was only detected after the exam when we ran a plagiarism detector on the answers.

It was decided that for subsequent exams, internet access would be restricted to websites on a whitelist (e.g. the submission platform itself), but this still presented two major problems. First, for technical reasons, students who were already connected to the router before the whitelisting was applied would still have unrestricted access afterwards. Second, it was still technically possible for students to access the internet via mobile hotspots with hidden SSIDs. Both situations were very difficult for invigilators to check for without being highly intrusive. A better BYOD solution was demanded that balanced the need for students to use a familiar programming environment with the need to provide sufficient safeguards against the plagiarism that is possible through unauthorised internet access.

SOLUTION

We identified three broad interdependent categories to consider in the design of our secure online programming exam. What *TECHNOLOGY* do we need to secure our students' devices? What *POLICIES* are needed to safeguard the exam? And finally, the *HUMAN* side: how will invigilators manage the exam, and who will support and troubleshoot issues?

In the 2019 iteration of Digital World, we designed and implemented a BYOD solution with the aim of covering these three bases. In terms of technology, we introduced "lockdown browser" to allow controlled access to cloud-based programming environments and our submission platform. Complementing this technology, we developed policies to ensure a consistent standard of invigilation across examination halls, and systematic procedures to follow for different levels of system failure. Finally, we designed briefing sessions for our invigilation teams, and benefited from the support of an in-house team for software issues.

TECHNOLOGY. Our technological solution used Safe Exam Browser (SEB), a lockdown browser that temporarily turns the students' laptops into secure workstations, limiting their access to unauthorised websites, applications, or system functions. With their workstations secured, we configured the browser to allow limited access to cloud-based IDEs, so that students could interactively develop and run programs in a controlled environment. Furthermore, we whitelisted our two submission platforms. One such platform was our LMS (Blackboard Learn), on which students answered concept questions that were designed to facilitate automatic grading, e.g. multiple choice, fill in the blank, true/false. Another submission platform was Vocareum (2019), a cloud-based Python Integrated Development Environment (IDE). Critically, this platform allowed students to run and test their Python code before submitting it, and having been used during class, was familiar to them.

SEB was the key technological element that allowed our LMS and Vocareum to be used safely. Apart from blocking software on students' laptops and non-whitelisted websites, as an added safeguard, SEB provides a "browser exam key" feature that can ensure that submission platforms will only work when accessed within SEB. For each exam, a unique (secret) hash key can be generated and provided to external platforms so that they can verify that students are indeed using the lockdown browser. While Vocareum implemented this feature for us, Blackboard Learn does not yet support it. This limitation meant that, without additional safeguards, the LMS part of the exam would potentially be accessible without SEB or even outside of the exam venue.

POLICY. To mitigate this current limitation, we put in the following policies as safeguards. First, students are told to arrive early for exam and launch SEB. At this stage, students must wait to enter a "settings password" to activate the browser, which is provided only 15 minutes before the start of exam. The questions on Blackboard Learn and Vocareum are protected by a separate "test password", requested by the LMS and Vocareum itself, and provided to students only after the invigilator has verified that all students have launched SEB. The test password is changed 15 minutes after the exam begins and is then known only to the invigilators, preventing students who leave the exam venue (e.g. for the bathroom) from communicating the test password to anyone outside.

To help eliminate the possibility that students access Blackboard Learn questions outside of SEB, we make use of the browser's "exit password" feature. The exit password is required to exit SEB, even in situations where the computer is forced to restart. This password is communicated only after the invigilators have verified that all solutions have been submitted.

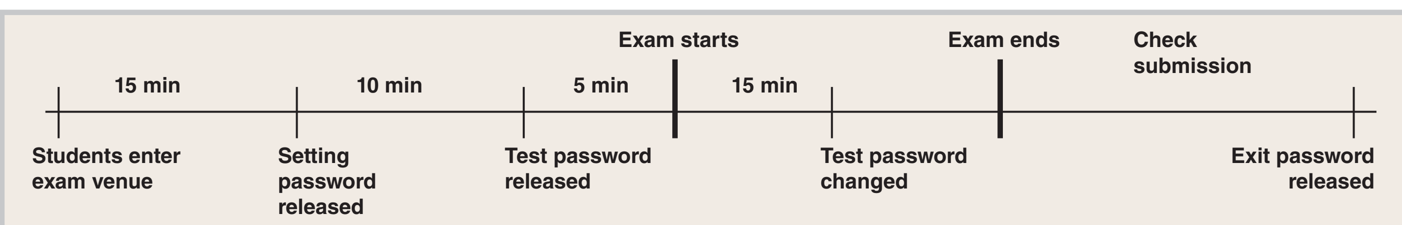

Figure 1. Timeline (not proportional) for key events in the Digital World exams

Given the multiple possible points of failure (SEB, LMS, Vocareum, WiFi, students' laptops), we systematically designed procedures for handling all combinations of failures. These involved backup submission platforms, backup IDEs, backup laptops, and in the case of total network failure, manual submission of answers on paper and USB sticks.

HUMAN. Finally, the human aspect played a critical role in the implementation of the exams, especially since they take place simultaneously across multiple classrooms. Invigilators had to be briefed so that they were familiar with all of these policies, especially the process of Figure 1, and the various procedures in case of technological failures. Our Educational Technology team also strongly supported us by conducting a mock exam, testing the software, developing the aforementioned policies, and providing support to invigilators and students during the exams.

REFLECTIONS

We first used this solution in a one-hour quiz before the mid-term exam with the entire cohort of Digital World. Despite conducting a mock test one week before the quiz, we ran into some difficulties that lead to several improvements for subsequent exams. First, with several hundred students using the platform at the same time, Vocareum was not able to cope with the computational load, leading to several students being unable to submit or test their answers. We worked with Vocareum to address the root cause of the issue, and took steps to reassure students of this. To manage the risk of Vocareum not working for any number of students, we identified Blackboard's native "Assignment" and "Journal" features as alternative means for them to submit answers, and updated our policies. There were a small number of students who were not able to launch SEB at all during the test. They were provided with backup laptops during the test, and the Educational Technology unit followed up. The typical reason was wrong version of SEB installed.

In the subsequent exams/quizzes, our BYOD solution worked more smoothly, aside from a few isolated cases which were managed by invigilators and Education Technology staff. As instructors, we felt that the effort required to design and implement this solution was worth the results it provided us with. First, confidence in the integrity of all submissions received. Second, an examination format that was close to the environment students learnt on (while still controlled). Finally, the convenience of being able to use technology in the marking process – automated grading for the LMS questions, and being able to run/debug students' code in the Vocareum part.

CONCLUSIONS

In this article, we have described how we implemented a BYOD solution for conceptual and practical programming exam questions, combining technologies such as lockdown browsers, LMSs, and cloud-based IDEs. We learnt that technology is only one of the key components to consider, and that developing proper policies, safeguards, and briefings is also important. With all these in place, our experience in Digital World has shown that (despite some initial difficulties) it is possible to successfully run a secure practical programming assessment in an environment that is better aligned to learning objectives.

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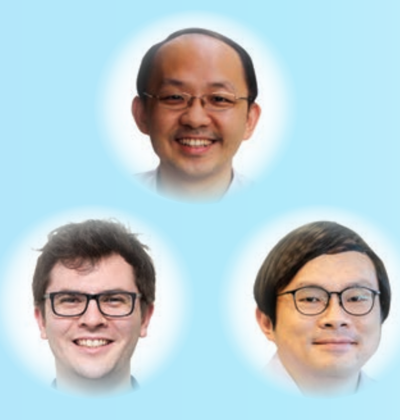

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Dr. Oka Kurniawan is a Senior Lecturer in Information Systems Technology and Design (ISTD). He has been leading the largest Introductory Programming Course at SUTD from the year 2015 till now. He is also in charge of an exciting course teaching students how computer works from the basic building block like transistors up to its operating systems. He has been involved in several educational research involving how to teach computing using games, robots, and recently AR/VR.

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Dr. Norman Lee *(right)* is a Senior Lecturer in Information Systems Technology and Design (ISTD). He currently teaches programming at SUTD, in particular, Python and Android programming (using Java). His current research interest is in learning analytics, especially in investigating the insights that can be gained by applying data-mining techniques to student data.

RUNNING ELECTRONIC EXAMS ACROSS MULTIPLE COHORTS

DR. STEFANO GALELLI, ENGINEERING SYSTEMS AND DESIGN (ESD)

General-purpose programming languages are becoming a pivotal component of many engineering courses, as they are an effective mean to implement and demonstrate the theoretical content delivered to the students. Python or Matlab, for instance, are used for a multitude of tasks, ranging from the implementation of numerical methods to the development of machine learning algorithms (Hoffbeck et al., 2016). Another relevant aspect of these programming languages is data visualisation, which is becoming an important skill in both academia and industry (Ryan et al., 2019)—libraries such as Matplotlib or ggplot2 now allow students to easily visualize multivariate datasets in Python and R.

As the evidence for the pervasiveness of programming languages expands, so too does the need for devising adequate strategies for assessing the students' programming skills (Fangohr et al., 2015). This entails determining the measurable outcomes, choosing the platform for delivering an exam (e.g., electronic or hand-written), and accurately planning the resources needed by both students and instructor (e.g., computer labs, IT personnel). Such planning exercise is particularly important when dealing with multiple cohorts, since the allocated resources must scale well to a large number of students. Here, I briefly elaborate on my experience with electronic exams that I gained through two ESD core courses, "Engineering Systems Architecture" (co-taught with Prof. Jackson) and "The Analytics Edge" (co-taught with Prof. Natarajan). Both courses introduce advanced engineering systems methodologies (e.g., multi-objective optimization, data analytics), so the exams cover a fairly large number of learning outcomes—e.g., from framing and formulating a multi-objective decision-making problem, to solving it through the aid of a computer programme.

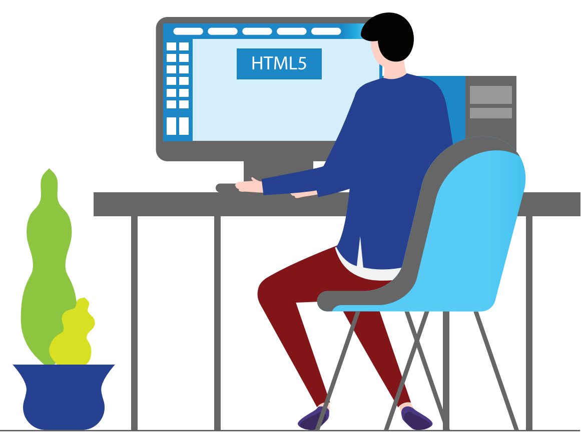
A first major decision concerns the 'platform' on which the exam must be carried out. This is typically a choice between an electronic exam (implemented, for instance, on eDimension) and a hand-written exam. Naturally, they both have some advantages and disadvantages (see Table 1): an electronic exam allows students to easily upload files (e.g., scripts, plots), but it is not the most convenient option for exams requiring both coding and analytical work. In such circumstance, a hand-written exam may be more suitable; yet, it would still require some support for uploading scripts and plots.

Another major decision concerns the computers used during the exam. This requires choosing between the equipment available in the computer labs and the machines owned by the students. Intuitively, one would choose the equipment available in the labs, since it provides a "standardized tool" to all

	Advantages	Disadvantages
Electronic exam 	Eases file upload	Not too convenient for questions requiring analytical work Students might struggle with some pre-defined options (e.g., inability to answer the same question twice)
Hand-written exam 	Allows students to easily carry out analytical work	Requires some support for uploading files

Table 1: Advantages and disadvantages of electronic and hand-written exams.

> "Another relevant aspect of these programming languages is data visualisation, which is becoming an important skill in both academia and industry."



	Advantages	Disadvantages	Resources needed
Computers owned by the students	✓ Students are familiar with computers and operating system	✓ Instructors limited ability to control computer settings	✓ Invigilators (generally two per exam venue) ✓ One person from the eDimension team ✓ One engineer from the IT office
Computer labs	✓ "Standardised tool" available to all students ✓ Controllable internet access	✓ Students may not be familiar with the installed operating system ✓ Unexpected malfunctioning of the computers	✓ Invigilators (generally two per exam venue) ✓ One person from the eDimension team ✓ One engineer from the IT office

Table 2: Typical advantages and disadvantages of an exam carried out in a computer lab or with the computers owned by the students.

students—it also allows the instructor to control internet access, if needed. Yet, the use of a computer lab comes with a few disadvantages (see Table 2): students may not be familiar with the installed operating system or struggle with some unexpected malfunctioning of the computers on the day of the exam. For these reasons, one may consider using the machines owned by the students: with this choice, there are lower risks of malfunctioning (students are responsible for the correct functioning of their computers). In addition, such choice reduces the amount of human resources needed—for example, it is not necessary to involve the personnel responsible for the labs. The pitfall stands in the instructor's limited ability to control the settings of the computers owned by the students.

In my experience, the choice of the computers used during the exam is the most critical. Some of the issues I faced when opting for the computer labs include the aforementioned malfunctioning, locked accounts (requiring IT assistance), and the inability of some students to work effectively with different operating systems. In addition, one must account for the coordination across multiple labs and the special-need students, who may be distracted by the presence of multiple students and IT personnel. Naturally, it is easy to handle all these issues and challenges when dealing with a small cohort; the problem stands in running an electronic exam across multiple cohorts.

In synthesis, I believe that it is paramount to test both analytical and programming skills of our students; yet, this requires an accurate and detailed planning of all resources needed for the exam, so as to guarantee a fair and smooth examination process.

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ARE WE READY FOR GENERATION Z?

DR. BINA RAI AND DR. LEO CHEN HUEI, SCIENCE AND MATH (SCI)

Colleges are transforming to remain relevant for the next generation. The newest students are changing the way schools serve and educate them (Global Research and Insights, 2018). A generation that rarely reads books or emails, breathes through social media, feels isolated and stressed but is crazily driven and wants to solve the world's problems (Du Plessis, N, 2011). The Generation Z (born after 1995) grew up playing computer games. They do not engage with textbooks that are finite, linear and rote. Based on the recent statistics of Pokemon Go players, the digital preferences of Generation Z are substantiated, with the greatest number of players (46%) aged between 19 and 29 years old (Forbes, 2016). To keep up with this digital revolution, teachers need to find online resources such as blogs and wikis that get them beyond the plain vanilla curriculum in the textbooks and come up with creative classroom set-ups (Cilliers, EJ, 2017). A recent report revealed that they disliked reading of any kind, possessed a work schedule that does not allow time for offline reading, and they prioritized their social life before reading. One particular study in 2018 (Fry A, 2018) assessed the use and compared the utilization rate of non-reference print and electronic book collection acquired during the same time period at one academic library. The author found that 74% of print titles acquired in 2008-2009 had been used within their first six years in the collection, and that 27% of print books acquired between 2008 and 2014 had been used between July 2013 and November 2014. By contrast, only 12% of the e-books acquired were used during this period.

The development of educational games have disrupted the education sector and changed how students learned. The Generation Z needs fast delivery of content with complex graphics. They are kinesthetic, experiential, hands-on learners who prefer to learn by doing rather than being told what to do or by reading text. Learning is not a spectator sport for them (Rothman, D, 2016; Dauksevicuite, 2016). Last year, Sibley et al, reported about a group of graduate students who tried out a computer-based simulation based on an International Market course. This simulation aimed to transfer skills from classroom to workplace. The simulation succeeded in arousing greater behavioral and emotional engagement among students. It has also helped students develop cognitive understanding of the topic and boosted theoretical ability to apply theoretical knowledge to real life situations. In a separate study by Cózar-Gutiérrez et al, a group of graduate students pursuing a degree in primary education participated in a computer-based simulation activity called MinecraftEdu. This is the educational version of the virtual world game Minecraft. Most of the students agreed that gamified simulations made the subject more interesting and that the activity promoted active participation and better engagement with content.

> *"Most of the students agreed that gamified simulations made the subject more interesting and that the activity promoted active participation and better engagement with content."*

Research regarding the effectiveness of games for science education is only beginning to emerge. Educational games are increasingly being used for learning biotech. Sadler et al, reported the implementation of a three dimensional biotech educational game (Mission Biotech), wherein gaming features were highlighted. A high learning outcome, particularly with lower-level students, was observed. Notably, researchers from Denmark (Bonde M.T. et al, 2014) showed a 76 % increase in learning outcomes by using a gamified laboratory simulation compared to traditional teaching and a 101 % increase when used in combination, suggesting an untapped potential for increasing the skills of science students and graduates. This study was tested on university students who were biology majors and the simulations were used in class as part of curriculum time. We were particularly keen to investigate if gamified laboratory simulations would be similarly or more effective as an online learning tool for our biology non-major undergraduate students at SUTD.

In line with SUTD's education mission, our students were divided into cohort classrooms (~45/class), where all the lessons are carried out in their freshmore year. The gamified simulations (Labster, 2016) were part of the compulsory teaching curriculum and tested in one of the weeks of Term 1, 10.006 "Natural World" module. We divided 10 cohorts of students randomly into 2 groups, control and simulations. For the classes' assigned simulations, 30 students tried the desktop (desktop-VR) and 15 students experienced immersive, VR simulations (immersive-VR) integrated into the lesson material (Fig. 1). The simulations consisted of lab techniques, learning tools and 3D visualizations that are available in a simulated environment. Throughout each simulation, students responded to questions to check if they have learnt the material and are ready to continue on to the next task. Students could only progress in the simulation, when they were able to answer correctly, ensuring that they utilized the theory and experiments fully instead of simply racing through the simulation.

The classes assigned to the control group were taught using the traditional method (powerpoint slides, chalk and talk). Students assigned to the immersive-VR accessed the simulations with VR Samsung Gear. The topic was DNA-based Technologies. We adopted the following two student learning outcome measures; 1. Pre- and post- quizzes (with 10 multiple choice questions that help students develop conceptual understanding) were used to compare the differences in acquired knowledge of the topic between the controls and simulations. (Crouch, C.H., & Mazur, E., 2001) 2. Student feedback survey (5 MCQs) about gamified lab simulation experience was collected to assess its effects on students' intrinsic motivation and self-efficacy. (Ryan, R.M., & Deci, E.L., 2000).

Data collected showed that the desktop-VR group of students achieved the greatest percentage improvement in quiz scores after the simulation as compared to controls and immersive-VR (Fig. 2). This correlated with the significantly reduced response times taken for quizzes too for the desktop-VR group. This may be attributed to the fact that the desktop-VR was a longer simulation, with in depth theoretical wikis and descriptions of relevant theory. Throughout each simulation, students responded to multiple-choice questions to check if they have learnt the material and were ready to continue on to the next task. The survey results gathered revealed that the majority of students perceived that the simulations improved their learning of DNA-based technologies, were motivated to complete the simulation and felt more confident at the end.

The Generation Z learns in a unique way and it is crucial for teachers at all levels to re-invent online learning resources to suit their style of learning. This will enable us to continue to engage, motivate and re-instill the joy in learning. This particular generation of students also prefer to do things themselves and appreciate active learning, hence our approach that evaluates

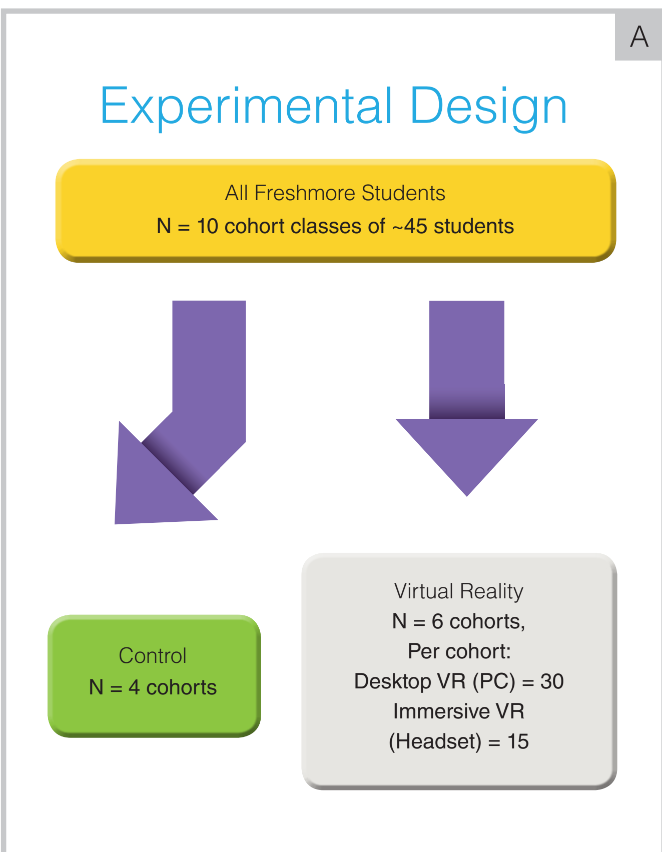

Figure 1: (A) Experimental design and (B-C) Photographs of students engaged in the desktop VR and immersive VR.

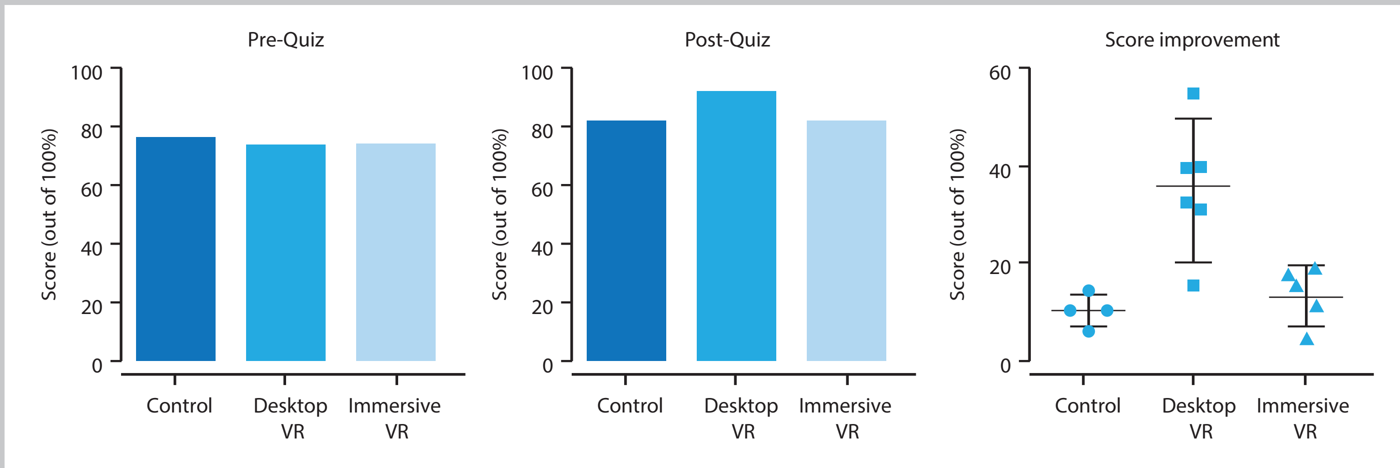

Figure 2. Mean quiz score achieved by students (A) pre- and (B) post- treatments. (C) The percent improvement in quiz scores from the 3 treatment groups. Plotted with SEM. N = 141 (Control), N = 113 (Desktop VR), N = 64 (Immersive VR).

gamified virtual lab simulations was well-aligned to their character. The results of our study support this hypothesis and we found that simulations lead to a boost in knowledge of DNA-based technologies and intrinsic motivation to learn biology in our students at the undergraduate level. This is an encouraging discovery for us and we plan to continue in our pursuit of finding ways to engage this new generation of students in a meaningful manner in the classroom.

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Dr. Leo Chen Huei *(right)* is Faculty Fellow for Science and Math Cluster. He teaches Freshmore Science subject and his research interests include active learning, flipped classroom, gamification and virtual laboratories.

TEACHING ATOMIC ORBITALS IN CHEMISTRY USING HAND-HELD 3D PRINTING TECHNOLOGY

DR. CHANDRIMA CHATTERJEE, SCIENCE AND MATH (SCI)

The concept of atomic structure forms an integral part of undergraduate chemistry curriculum as it provides a valuable insight into the properties of different kinds of materials. A complete understanding of atoms requires knowledge of quantum mechanics even for an introductory chemistry course. Concepts in quantum mechanics are very abstract since most of the phenomena described by this theory cannot be observed directly. One such topic is atomic orbitals, which are interpreted as electron clouds showing how electrons are distributed in a 3-dimensional (3D) space. Comprehending this idea can be quite challenging for students since it requires them to do lot of visualization of 3D structures and most text books often use the two-dimensional (2D) representation.

At Singapore University of Technology and Design (SUTD), students are introduced to the basics of quantum mechanics during the Integrated Learning Program in Chemistry (ILP2 Chemistry). This is a bridging course that aims to equip students from diverse pre-university backgrounds with sufficient general chemistry concepts to smoothen their transition into the SUTD Freshmore curriculum. However, owing to the abstract nature of this theory, students find it very hard to grasp the concepts, as reflected in the following feedback provided by students who have completed this course.

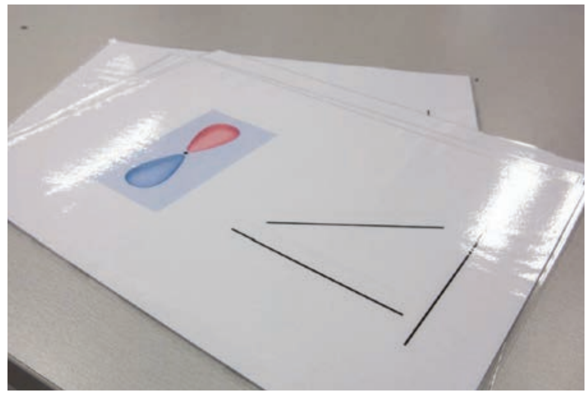


Figure 1. A template with a basic drawing of atomic orbital in two dimensions (2D) provided to the students.

Figure 2. Students from ILP2 Chemistry working in groups to generate atomic orbitals of their choices using the hand-held 3D printing technology.

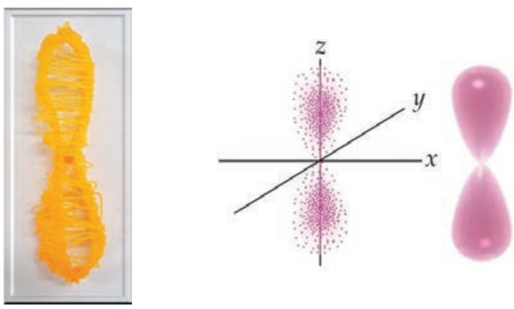


Figure 3. Left: The p-orbital created by students using 3D pens. Right: A textbook representation of a *p*-orbital.

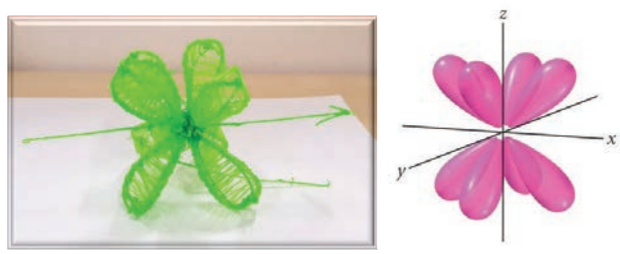


Figure 4. Left: One of the f-orbitals created by students using 3D pens. Right: A textbook representation of this *f*-orbital.

Different kinds of tools have been developed and applied to assist in visualizing the shapes of the atomic orbitals, including computer animations, (Manthey 2004) and computation laboratories (Ruddick 2012). However, these approaches are more suitable for in-lecture demonstrations. It is beneficial for the students to get a hands-on experience on how to construct 3D structures of the seemingly abstract atomic orbitals.

3D printing technology is finding an increasing use as a learning tool in chemistry classrooms. 3D printed models have enabled instructors to teach a wide range of topics in chemistry, including molecular orbitals (Robertson 2015), symmetry and point group theory (Scalfani 2014) as well as structure energy relationships (Blauch 2014). A recent development of the hand-held 3D printing pen has further facilitated both instructors and students to build 3D models in the classroom itself alleviating the need for creating a file that is required as an input for conventional 3D printers. Using this portable 3D pen, which extrudes hot plastic at one end, students can generate 3D structures from drawings in two dimensions (2D). This method has earlier been used to teach VSPER theory and has been found to be a very effective learning tool (Dean 2016). In this article, it is demonstrated how this hand-held 3D printing technology is currently being used in ILP2 Chemistry to construct 3D atomic orbitals.

In this activity, students are required to work in groups and make atomic orbitals of their choice using a 3D pen, with polylactic acid (PLA) as a material for the filament. A template with a basic image of an orbital in the shape of a balloon is provided to the students (Figure 1). This drawing in two dimensions was prepared using Microsoft PowerPoint. It was subsequently printed on a piece of paper and finally laminated. Using the hand-held 3D pen, students trace over the 2D sketch and apply multiple layers of the molten filament over the same for constructing atomic orbitals in three dimensions (Figure 2).

In order to replicate the geometry of atomic orbitals, students generate multiple structures of the balloon-like shape and then join them together using the molten plastic extruding from the 3D pen. For instance, a *p*-orbital which mimics a dumbbell is created by making two lobes in three dimensions and subsequently combining the two pieces together in the shape of number eight (8). Likewise to produce one of the seven f-orbitals, students construct 8 balloon-like lobes and assemble them together in the shape of a flower. Figures 3 and 4 show the p and the *f*-orbitals respectively that were developed by students using the 3D pens. The text book representation of these orbitals are also shown side by side for the purpose of comparison.

At the end of this activity, each group presents the atomic orbital that they created to the class explaining its shape as well as its orientation in a three-dimensional space. In fact, some groups also duplicated the 3-dimensional axis system (x, y and z) in order to demonstrate the orientation of these electron clouds (Figure 5).

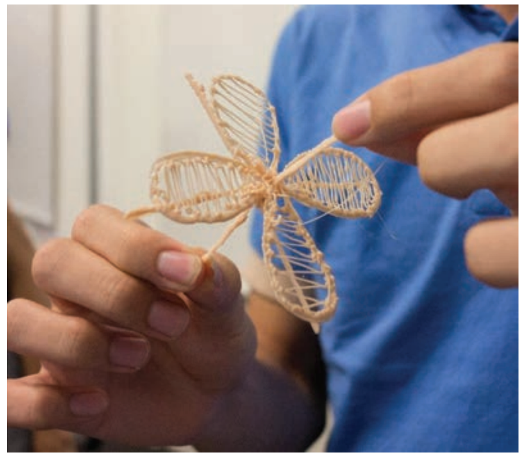
This learning exercise was found to be engaging and exciting for the students since they get a hands-on experience on how to build 3-dimensional geometries using contemporary technology. In addition, they had fun producing colorful structures. Students often request for filaments with colors of their choice. This relatively new pedagogical strategy in combination with other active learning exercises implemented for teaching quantum mechanics have further helped in improving the course feedback for ILP2 Chemistry. It has enhanced students' understanding of abstract concepts as reflected in the following comments:

"I learned a lot from the chem class and the hand working sections were reeeeally nice!"

"Dr Chandrima is passionate in her subject, and tries to incorporate interesting activities into the class to engage with students, and help us understand concepts better".

"Very useful and all the activities are interesting. It's a wonderful class."

One of the drawbacks of using the 3D pens is that the structures can be a bit fragile. However, it was observed that by applying multiple layers of the filaments, the strength of these models can be improved. Another issue with the 3D pen is that the filament can get solidified at the tip thereby preventing further extrusion of the molten plastic. It was noted that some students tried to troubleshoot this technical issue, which indirectly provided them with an opportunity to hone their technical abilities. In conclusion, the application of hand-held 3D printing technology offers a fresh and innovative teaching approach to facilitate student learning on three-dimensional models. Students applied state-of-the-art technology to construct 3D structures of electron clouds. In the future, this technical method can be expanded to generate molecular orbitals in three dimensions to further enhance students' learning experience.



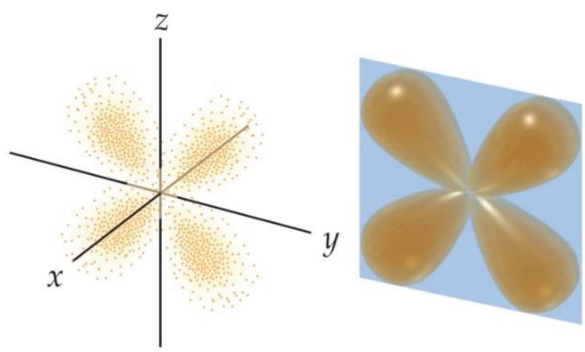


Figure 5. Above: Shape and orientation of an off-axis d-orbital produced by the students.
Bottom: A textbook representation of an off-axis d-orbital.

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TEACHING RESOURCES

COLLABORATION BY DESIGN

MS. TEO SU CHERN, SCIENCE AND MATH (SCI)

Figure 1. Collaboration by Design, Capstone Class of 2017

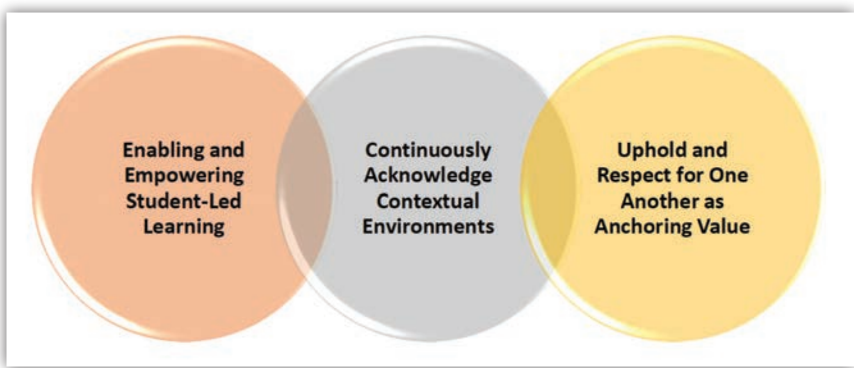
BACKGROUND

"Collaboration by Design" is a class which was originally created, designed and launched in January 2017 for all SUTD Capstone students. Capstone students form teams of approximately 5 – 7 students, working closely with industry partners and capstone faculty mentors on design projects that solve real-world problems. Capstone student teams are a unique composition of multi-disciplines and collaborate on their Capstone projects for two academic terms, a longer time commitment than other student teams in SUTD. The module was thus created to guide Capstone students in delivering synergistic value and developing the full potential of their design teams, thereby empowering deep learning, meaningful team experiences and impactful team outcomes for all students and stakeholders involved.

After the first run of "Collaboration by Design" for Capstone students, participants requested that the module also be extended to their first-year juniors, recognizing that such a class would also be valuable when the design curriculum was first taught to freshmore student teams. "Collaboration by Design" was thereafter formally incorporated into the 3.007 Introduction to Design curriculum in SUTD and introduced to SUTD freshmore students in September 2017.

FUNDAMENTAL PRINCIPLES

"Collaboration by Design" classes are grounded in and led by 3 fundamental principles:



1. Enabling and empowering student-led learning.

This is emphasized for two main reasons. Firstly, students develop confidence in appreciating and flexibility in managing the myriad complexities and intricacies that they will invariably encounter in their team interactions. Secondly, student-led learning promotes a community of trust and support within the student community that will serve as an additional resource to students.

2. Continuously acknowledging the contextual environments in which SUTD student teams operate.

Collaboration as a topic is examined and discussed through the existing collaborative routines, habits and behaviors of SUTD students and student teams, so that learning tools and insights can be embedded within the relevant contexts of SUTD students. The understanding of student concerns, and the wider environments that interact with their team dynamics is constantly updated for relevance to learning.

3. Upholding and emphasizing respect for one another as an anchoring value.

A safe and trusting space created from respect for one another is essential for meaningful in-class interaction and participation, particularly when students are invited to participate with a high-level of visibility. Students are further encouraged to continue to guide their responses and collaborative interactions from a place of respect.

STRUCTURE

The structure of the module for freshmore and Capstone student participants differ slightly, however, the module generally takes the form of a short lecture, at least one cohort class, team discussions and one-on-one student conversations. The format of the module ensures that a balance is met between introducing conceptual frameworks and collaborative principles in a succinct manner and building in time for student teams to get to know their teams, put concepts into practice, ask questions and learn from one another.

CLASS FORMAT

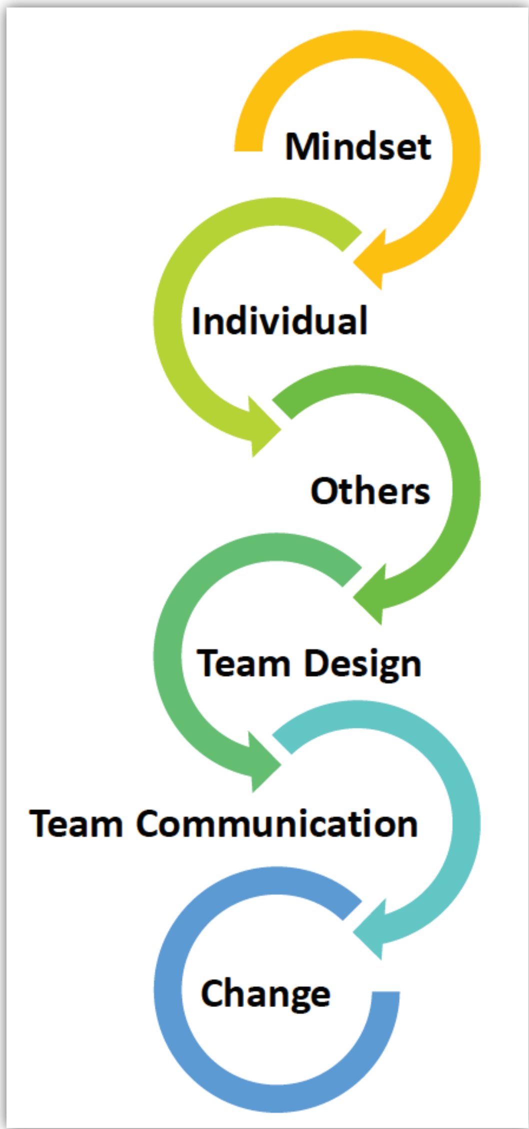
All classes are designed to be interactive. Students are invited to engage with one another and with the instructor in a laptop-free environment. A laptop-free environment can be a radical shift in modus operandi for most students, however, SUTD students have been positive and cooperative, putting aside their devices to focus on their teams and learn from one another. Students thus engage with one another in a classroom setting but in a deeper, more intentional way. "Collaboration by Design" classes are highly engaging, building energy and engagement through scenarios and activities that encourage face-to-face interaction among students and provoke reflection and dialogue within teams.

Figure 2. Team Activities, 2019

CLASS CONTENT

"Collaboration for Design" classes cover the following content:

- **Mindset:** Adopting a learning mindset and using the opportunity to work in teams as a rich learning opportunity, viewing conflicts, challenges and struggles as areas for learning through conversation and dialogue, introspection and shifts in behavior.
- **Individual:** Cultivating an understanding of one's preconceptions, expectations and motivations around collaboration, including considering one's resources in the form of strengths, achievements and past contributions, as well as one's weaknesses and vulnerabilities in collaboration.
- **Others:** Cultivating an awareness of one another in contexts broader than a task-focused, competency-based understanding.
- **Team Design:** Designing and creating unique structures and tools to enable teams to reduce some uncertainty in their collaborative practices and environments, and to introduce clarity and accountability among team members.
- **Team Communication:** Encouraging and practicing respectful and meaningful communication with one another, recognizing the role of assumptions, understanding the tool of feedback and simplifying the spirit and process of communication to core principles applicable to social norms.
- **Change:** Accounting for the role of change in the evolution of teams or in collaborative environments so as to prepare for foreseeable changes or respond mindfully to what has changed.



TEAM DISCUSSIONS AND ONE-ON-ONE CONSULTATIONS

To address the unique issues that each team faces, team check-ins are held with student teams to optimize team functions, enhance team clarity and work through other team issues that have arisen. One-on-one consultations are also held with individual students keen to consult on further questions around collaboration or receive coaching support and guidance for their collaborative experiences.

COMMON THEMES

Common themes on collaboration regularly emerge from working with student teams. Students who have received support and guidance in the following areas generally report higher levels of engagement, team resilience and team morale.

- **Leadership:** Leadership in teams is a topic that comes up often among students, particularly since students work in teams of peers with no formally assigned hierarchy. Students also value maintaining harmonious relationships and social networks.
- **Priorities and agendas:** A large proportion of SUTD students are enthusiastic and active in engaging with a multitude of experiences and roles, particularly as these serve as tremendous learning opportunities for them. Some students experience overloaded schedules and consequently, conflicts in commitments create spillover effects on their teams.
- **Interpersonal communication:** The communication of one's stand or opinion to others, particularly a differing one, is a vulnerable act with a high level of perceived risk, and a common challenge faced by students. Support offered to students ranges from examining individual expectations around communication to reworking team norms around intra-team communication to working with team conflict through meaningful team communication.

COLLABORATION OUTSIDE CAPSTONE

Apart from their Capstone team experiences, students have also offered a range of other collaborative experiences for consultation. These range from past internship experiences in industry to current challenges working in start-up teams and teams serving commercial clients. Students are frequently interested to deconstruct their experiences, capture personal learning and formulate personal strategies in working with teams outside of the SUTD domain.

STUDENT RECEPTION

A recurring sentiment from students is a deep appreciation for the space set aside in "Collaboration by Design" classes for students to interact with their team mates outside of their project and to be in deeper dialogue about working with one another. The enthusiasm that students during class is evident – apart from the presence of laughter and conversation, students demonstrate high levels of creativity and multidisciplinary contribution when provided with a platform to express their team stories and views. Many teams have created delightful and memorable presentation pieces and commentary from class activities.

Students have also been very positive about being able to devote time to honing collaborative skills and engaging in topics like interpersonal communication or team engagement. Many such topics have generally felt challenging to them or have not been formally taught in their past academic curricula, and students appreciate the language and perspectives offered to assist them to articulate their experiences and challenges. Capstone students, mostly in their final year at SUTD, often note how sharpening their ability to work with people can position them strongly for the next phase of their life, where the stakes of their day-to-day, their environments, and interpersonal interactions change vastly. Many Capstone students thus present valuable and pertinent questions on collaboration, whether in class or in consultations, that provide meaningful learning contexts and outcomes for other students.

THE FUTURE IS BRIGHT

It has been heartening to observe and interact with SUTD students in their participation and learning of collaborative skills. Students have demonstrated enthusiasm and diligence in their learning, proactivity in engaging in dialogue and a commitment to human-centredness. These attributes, coupled with the technical and collaborative skills that SUTD students possess and will continue to hone, will serve and position SUTD students very well, and importantly, empower SUTD students to offer tremendous impact and promise to the worlds that they engage with and most certainly, for the better world that they are already creating.

> "Capstone students, mostly in their final year at SUTD, often note how sharpening their ability to work with people can position them strongly for the next phase of their life, where the stakes of their day-to-day, their environments, and interpersonal interactions change vastly."

ABOUT THE AUTHOR

Ms. Teo Su Chern is an Adjunct Lecturer at SUTD teaching "Collaboration by Design" as a core module for first- and final-year students. She has co-designed and co-led "Team Dynamics" and "The Leadership Series" in SUTD, totalling more than 15 workshops in SUTD to over 300 participants, ranging from students to post-docs.

CREATING A SAFER WORLD BY DESIGN:

ENVIRONMENTAL, HEALTH & SAFETY (EHS) RISK MANAGEMENT COURSE FOR CAPSTONE STUDENTS

MARC LOUIS SOH, SENIOR ASSOCIATE, ENVIRONMENTAL HEALTH AND SAFETY (EHS)

With increasing demand for thinkers and problem solvers, prospective employers expect graduating students to meet higher expectation. To address this, SUTD broke from the tradition by offering final year students a more holistic approach through the "Capstone" programme where students are heavily involved in project management. This programme allows students with different expertise to come together and brainstorm for solution to real life issues. The Capstone programme also provides students with an opportunity to gain hands-on experience through building, assembling and operating their prototypes in the University-industry partnership.

Design projects always carry certain level of risks and have implication on safety issues. It is very important and critical for every student to observe safety during their course in SUTD, as any accident would potentially cause undesirable outcomes such as injuries and/or property damage which can negatively impact the student's experience with us and the reputation of the school.

SUTD EHS RISK MANAGEMENT COURSE

SUTD's Environmental, Health and Safety (EHS) team successfully launched the in-house EHS Risk Management course for all capstone students on 29 January 2018. The certified course was developed by the EHS team following the guidelines by Workplace Safety and Health Council (WSHC).

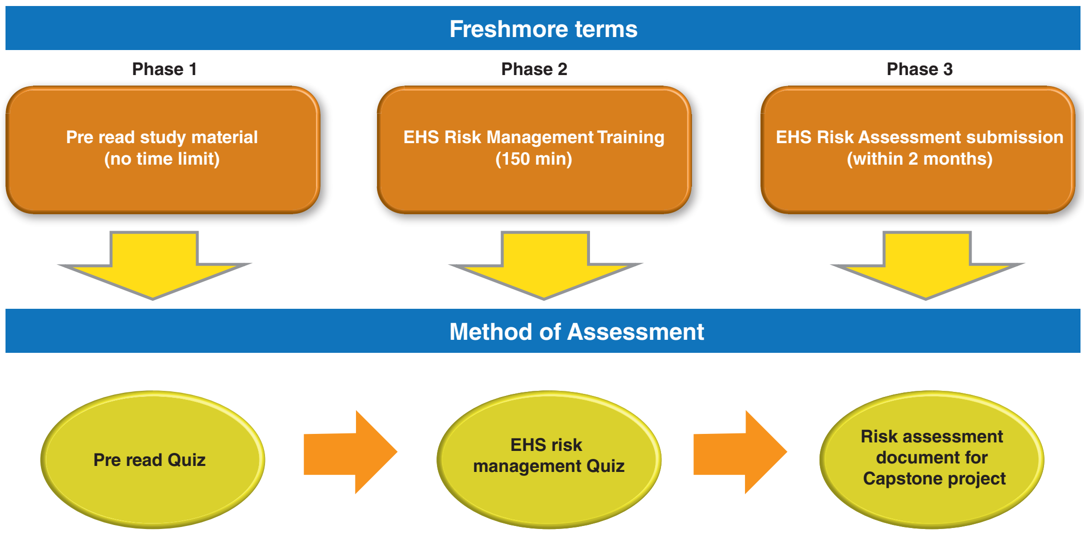
SUTD EHS Risk Management Course for Capstone Students educates students on the Singapore Standards of Workplace Safety and Health (WSH) legislations with key focus on WSH (Risk Management) Regulations.

The knowledge-based component of the course focuses on hazard identification risk management process, and skill based training where the student can apply what they learned in realistic situations. The key learning outcome for this training focuses on deeper understanding of risk assessment in routine and non-routine activities and also imparting technical knowledge and skills that can be applied in their final year Capstone projects.

SUTD students access their course material and assessment through SUTD's learning management system. EHS adopted a 3-Phase teaching process to deliver our training. At the beginning, students are required to complete an hour of pre-reading materials before attempting the pre-class quiz consisting of 3 case studies, aiming to prepare them for upcoming instructor-led sessions.

Phase 2 uses face-to-face learning experience to improve the training experience. Visual aids such as safety related video clips and slides provide the students with examples of several EHS concepts such "5 by 5 risk matrix", "Hierarchy of controls", "considerable factors", which are among some of the important points to take note when conducting hazard identification and risk management. This 150-minute session ends with students completing an online assessment involving 10 short-structured questions. Students are required to achieve at least 70% correctness to pass the quiz. Finally, those who have gone through Phase 1 and 2 are able to proceed to conduct their risk assessment for their respective projects and submit their documentation to EHS. EHS will review the document and if needed, will work with students to make the project work safe.

Lesson Plan of EHS Risk Management Training Course for Capstones Students



CHALLENGES

Moving into the digital age, learners are becoming more tech-savvy as information is readily available online. They are also constantly distracted by their electronic devices. As such, keeping them away from such distraction is one of the key challenge besides getting them interested in safety as students are constantly rushing for lessons and multi-tasking. As trainers, we are constantly making changes to our teaching approach in order to be more connected with the learners. Things such as visual resources, online learning platformshelps to create a more inclusive environment to enhance learners understanding in risk management. Lack of active participation during the training is often linked to poor understanding of the content and skills. Hence, creating safety cultural awareness and interaction through promotional activities such as workshops and EHS week events would often bridge these gaps. helps to create a more inclusive environment to enhance learners understanding in risk management. Lack of active participation during the training is often linked to poor understanding of the content and skills. Hence, creating safety cultural awareness and interaction through promotional activities such as workshops and EHS week events would often bridge these gaps.

SUMMARY

In a nutshell, educating safety at SUTD takes on a more active approach in developing the safety culture in the organization. Unlike many other developed industries such as manufacturing and construction where safety is a 'top down" approach, the institute of higher learning and research sectors are often struggling with adopting the industry standards because we are considered the low risk industry. Having said that, the university is producing year on year batches of students who are going to be the next engineers and architects which is why it is very important that these professionals who are shaping the world are also working with safety in mind. In order to do that, we are also collating student feedback to gain deeper understanding on what works the best for these students. In addition to that, EHS also looks forward to developing online interactive training sessions so that learners can do their own training and assessment since such approaches will benefit the learners as they are in better control of their time and schedules. Our hope is to be more student-focused and to create improvement for continual learning in safety.

Acknowledgements: We would like to thank Dr. Nachamma Sockalingam from Learning Sciences Lab for framing this article pedagogically.

ABOUT THE AUTHOR

Mr. Marc Louis Soh is a safety professional with Singapore University of Technology & Design. He holds the position of the Senior Associate (EHS) and leads the in-house workplace safety and health risk assessment training and development curriculum.

LIFELONG LEARNING FOR LIFELONG EMPLOYABILITY

DR. ONG ENG HONG, DIRECTOR, OFFICE OF UNDERGRADUATE STUDIES (UGS)

We are witnessing how our work place has been impacted at a rate we have never seen before by the advent of emerging technologies such as artificial intelligence (AI), robotics and Internet of Things, etc. And at the national level, the need for our working population to up-skill or re-skill themselves to stay relevant in the industry has never been as urgent as it is today. As coined by New York Times columnist Thomas Friedmann, we are now living in "the age of acceleration", where the rate of technological advancement is fast outpacing the rate of human adaptability. It is easy to see that lifelong learning is key to lifelong employability.

SUTD Academy was officially launched on Jan 10, 2018, to support continuing education and training for working adults in areas such as design innovations, cybersecurity, data analytics and AI, engineering, urban solutions and tech-enabled services, just to name a few.

We have since formed strategic partnership with leading organizations from the public sector, private sector, education sector and professional bodies to identify urgent training gaps in the workplace, so as to co-develop and deliver highly relevant and essential training courses in a timely manner. Apart from relying on our own academy fellows who are SUTD's faculty members and staff members, we also engage individual leaders or experts from the industry to be our adjunct fellows, thereby augmenting our team of quality instructors.

PEDAGOGY AT SUTD ACADEMY

SUTD has been set up to groom technically grounded leaders to take on challenges of the 21st century. And SUTD Academy aims to reach out to the greater working population so that they can also benefit from SUTD's unique value proposition, one that embraces active learning, multi-disciplinary approach, design thinking and entrepreneurial spirit.

At SUTD, we stress a lot on applying design thinking in the design of our curriculum and pedagogy. We put a lot of thoughts into understanding the needs of the learners and design high value added curriculum that tends to engage the learners intensively during a class. There are more hands-on activities and active learning through small group discussions during a class, and there is more quality interaction between the learners and the instructor. Trainees typically learn more effectively and efficiently during our classes which helps them to perform better at work place.

We have specially designed learning spaces to enhance students' learning experience too. Instead of conducting classes at only lecture theatres or general purpose classrooms, we conduct many of our classes at specially designed cohort classrooms where furniture is easily reconfigurable to facilitate small group discussions and the various teaching aids available in the classrooms help students to focus and learn better. Especially for cybersecurity, we have a state-of-the-art cyber physical system that has proven very useful for the teaching and learning of cybersecurity.

MODULARMASTERS PROGRAMME

In addition to offering individual courses, we provide multiple pathways for the interested to work towards formal and official recognition of advanced skills and knowledge acquired through trainings offered by the SUTD Academy. For example, we launched on June 18, 2018, a nation's first of its kind ModularMasters (MM) in cybersecurity which can in turn provide a pathway to Master of Science in Security by Design (MSSD), a master's degree offered by SUTD.

The Modularmasters programme allows adult learners to enrol themselves in bite-sized skills-based modular courses (SMBCs) that carry subject credits, and aggregate the credits to earn an MM certificate. SUTD Academy has also partnered Temasek Polytechnic to allow trainees taking recognised modules from Temasek Polytechnic to transfer over a set

Figure 1. Photograph of Minister for Education, Mr Ong Ye Kung (centre), SUTD President, Prof Chong Tow Chong (second from right), Apple's Vice President of Environment, Policy and Social Initiatives, Ms Lisa Jackson (third from left) and other VIPs at Apple's launch event on March 14, 2019 to promote coding skills.

number of subject credits to SUTD Academy if they wish to earn an MM in Cybersecurity. An MM certificate in cybersecurity requires 60 subject credits.

For adult learners who wish to further their studies upon completion of the MM programme, they may apply to SUTD to pursue the Master of Science in Security by Design (MSSD) degree by passing an entrance assessment examination and meeting other entry requirements subject to SUTD's admission criteria for the MSSD. Upon admissions, they can use the MM in Cybersecurity certificate to contribute partially towards the total required subject credits for graduation from the MSSD programme. We are currently developing similar MM programmes in other technical areas with our strategic partners.

INDUSTRIAL PARTNERSHIP

We also see ourselves as a worthy partner who works with and provides support to the industry with our unique pedagogy and curriculum as it undergoes digital transformation with our unique pedagogy and curriculum. According to World Economic Forum Report published in 2016, 65% of children entering primary school in that year will ultimately end up facing completely new job types that don't yet exist. But what we can envision is that such new job types will require a lot of digital skills, as digital technology is going to be ubiquitous and one can be rendered handicapped without mastering digital skills. Hence, to master digital and coding skills is to master the language of the digital age and it opens up a lot of new opportunities for us, especially in enhancing our employability.

We are therefore glad to share that we are the only institute of higher learning in Singapore that Apple has chosen to partner with in co-creating coding courses for adult learners.

SUTD Academy has also gone international leveraging SUTD's unique strength in design thinking and design innovations. With Temasek Foundation International and Suzhou Industrial Park Administrative Committee as partners, SUTD Academy provides training in design thinking to pre-u teachers from Suzhou Industrial Park through a 3-year programme, Innovation and Enterprise Programme with Chinese Characteristics for a New Era. The programme was launched in Suzhou Industrial Park on Jun 20, 2018 and we have received rave reviews for the workshops that have been conducted thus far under the programme.

All in all, SUTD Academy strives towards offering high value added trainings to help working adults stay in sync with technological advancements for enhanced employability.

ABOUT THE AUTHOR

Dr. Ong Eng Hong is the Director for SUTD Undergraduate Programme, Office of Undergraduate Studies. He is currently driving the smart campus initiative, exploring how to advance technology-enabled learning to the next level of excellence with state-of-the-art technologies in virtual reality, artificial intelligence, internet of things, etc.

IDiA LAB

A HUB FOR VIRTUAL AND AUGMENTED REALITY DEVELOPMENT, APPLICATION AND EDUCATION

DR. LIN WUZHONG, DEPUTY DIRECTOR, OFFICE OF UNDERGRADUATE STUDIES (UGS)

Innovative Digital Arts (IDiA) Lab, a physical workspace at SUTD, has been playing a critical role in providing a space for creation and innovation as well as a forum for education and collaboration in the areas of digital arts, graphic design, print media, 3D modeling & animation, mobile & desktop application programming, and game development. The IDiA serves in several ways as the digital counterpart to the Fab Lab, in particular, the IDiA Lab seeks key areas of excellence including visualization of data and innovative use of interfaces and input technologies.

IDiA lab has now been evolving into a hub for immersive virtual reality (VR) and augmented reality (AR) for education and research - equipped with state-of-the-art 360-degree VR camera, head mounted displays and high-performance computers as well as 3D gaming software for VR/AR content development and visualization.

As commonly understood among the institutes of learning, applications of immersive VR and AR technologies greatly enhance and transform undergraduate education, creating a more interesting, helpful and interactive learning and teaching experience in the classroom -- resulting in measurable and positive impact on students' learning experience both in short- and long-term with more in-depth and long lasting knowledge beyond traditional lecture-based teaching methods. SUTD is also striving to keep abreast of and consistently adopt these new technologies in its undergraduate curriculum delivery and innovative pedagogy.

Figure 1: Immersive VR learning experience at IDiA Lab

At IDiA Lab, students can experience immersive virtual environment for learning and also learn how to make use of software, such as 3D gaming software Unreal or Unity to create and develop VR/AR contents. For example, faculty and students from Architecture and Sustainable Design (ASD) pillar have used 3D gaming software Unreal and VR technologies in their architectural design course, allowing designers to develop virtual scenes and digitally immerse themselves to experience the space they are designing, and make adjustments to their design - breaking through both time and space constraints. In a specific topic of 'Digital Archive", students learn how to combine virtual reality to design "virtual libraries", "virtual museums", and even "virtual cemeteries" to name a few, to store information, cultural relics, and even memories of deceased relatives, as a future method of collection and preservation. This course is taught by Practice Professor Eva Maria Castro

IDiA Lab is open to the whole SUTD community.

For more information of the IDiA Lab, please contact: Cherish Chan Xiao Si at cherish_chan@sutd.edu.sg

ABOUT THE AUTHOR

Dr. Lin WuZhong is the Deputy Director for SUTD Undergraduate Programmes. His current work focuses on the conceptualization, implementation and management of technology-enabled academic facilities and spaces for education.

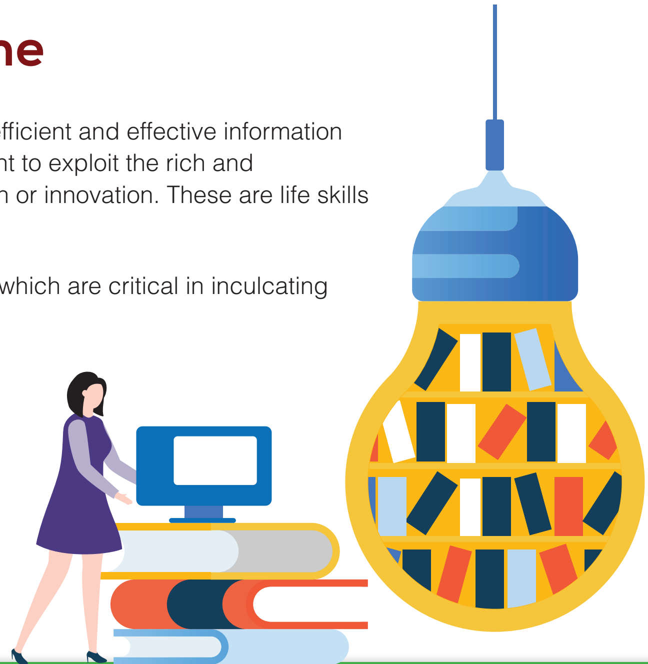
Our Support to the SUTD Community:
Value-added Research and Trainings

SUTD LIBRARY

SUTD Library Training Programme

As information professionals, we aim to equip every SUTD student with efficient and effective information searching and research skills. These skills enable each and every student to exploit the rich and authoritative academic resources and create value through their research or innovation. These are life skills that will also be useful when students venture out to work.

The Library Training Programme includes citation and referencing skills, which are critical in inculcating students to avoid plagiarism and upkeep academic integrity at all times.



Content

Content of workshops and trainings cover areas such as:

- Research Skills
- Research Strategies
- Research Tools
- Information Search Strategies
- Scholarly Writing Skills
- Authoritative Sources based on specific topics
- Avoiding Plagiarism: Citation and Referencing Skills

Delivery Structure

Three categories of training are conducted:

- In-Class (incorporated into the Curriculum)
- Core (Literature Review, Research, Citation, Plagiarism)
- Soft skills (Life-long learning)

In-class sessions are trainings and workshops conducted in collaboration with the faculty. They are aligned and customised to the course curriculum. The content is developed based on the requirements provided by the faculty. Some examples are referencing and research skills trainings conducted for Freshmore (First year students) and capstone project (Final year students).

Core (Literature Review, Research, Citation, Plagiarism) are small-scaled on-demand workshops & clinics sessions. From these sessions, the attendees will be able to understand the what, why and how on each of the topics. The librarians can provide consultations to anyone who need further clarifications or elaboration on the topics.

Endnote Training

is one of the workshops conducted under our 'Information & Research Literacy Skills Programme'. Endnote is a licenced software that aids the academics, researchers and students to effectively manage their references and efficiently cite the critical works in their papers. The software allows the writers to change from one citation style to another seamlessly at a click of a button. In these trainings, users will be trained from getting the software installed onto their system, to how they are able to efficiently generate the reference / citation list to be included into their papers.

Soft Skills (Life-long learning courses) are online courses identified by the SUTD Library Training Team to enhance one's skill set. These set of skills are acquired through self-directed learning.

For specialised databases, the library invites database providers to conduct workshops and provide more in-depth information to the users.

You can drop an e-mail to SUTD Library (library@sutd.edu.sg) for any training requests OR fill up a request form at SUTD Library website (library.sutd.edu.sg > Self-Help > Make a Request > In class Training)

Photo by UN Studio SUTD © Hufton+Crow

ASK Library and LEARN how to exploit the services and resources available for you!

Email: library@sutd.edu.sg

The Materials Collection and Its Use for Teaching and Learning

As part of the SUTD Library's ongoing effort in providing quality hands-on learning experiences, the library is enhancing our physical materials collection to better complement design and materials related courses so as to provide the SUTD community with the most relevant materials.

Currently the SUTD Library holds more than 600 physical materials, of which 75 materials are internally sourced materials. We are expanding to feature more internally sourced materials, with various faculty across EPD and ASD to help us curate and source for fundamental materials that are highly referenced and taught in class. In addition to the fundamental materials we are adding to the collection, we are also working with DmanD to feature various research and applications of additive manufacturing using various materials and techniques.

The enhanced materials collection will feature a spectrum of materials from fundamentals like timber, bamboo, polymers, metals to finished products like medical devices and assembly systems. Instead of learning from pictures, students can reinforce their knowledge with the sense of touch and allow them to compare the different material texture and weight. Users can easily take any material to their seats, scan a QR code for more material information or browse the handy A5 infocard with vendor listing so that they know where to find these materials if they need them for prototyping. For further research on materials properties, the library provides a dedicated computer terminal with CES Edupack by Granta and ASM Materials database.

We are also working on providing material sets that faculty members can borrow to facilitate their lesson on fundamental materials, giving students the same material discovery experience in their classrooms.

If you have any suggestions or recommendations to be included into the collection, please contact us at library@sutd.edu.sg.

LSL SERVICES

- Introductory Teaching Course
- Pedagogical Workshops
- Distinguished Educator Series Talks
- Faculty Educational Development
- Scholarship of Teaching and Learning (SOTL)
- SUTD SOTL Circle Interest Group
- Asian SOTL Circle
- Pedagogical Research: Consultation & Collaboration
- Teaching and Learning: Consultation & Collaboration
- Pedagogy Day
- Pedagogy Newsletter
- Online Resources and Communications
- Grant Proposal Review

ABOUT LSL LOGO

LEARNING
SCIENCES
LAB
OFFICE OF
UNDERGRADUATE STUDIES

The three jigsaw puzzle pieces represent the various stakeholders involved in Teaching and Learning – This could be LSL, faculty members and educational leaders; or it could be LSL internal and external stakeholders, with LSL playing a central and crucial role in connecting the various stakeholders, towards exellence in teaching and learning at SUTD. The three pieces come together to form the shape of "L" signifying the ultimate focus to be on learning and learners.

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