

Physics Matters

General Education Reform

General Education (GE) is not new in the NUS curriculum. Even with the best intention and implementation strategies, all great initiatives have to undergo constant review in the face of new challenges. This explains the need for a review and a new GE structure to be introduced in the coming academic year.

Underlying the GE program at NUS is the concept of an educated person, expressed as: Regardless of the choice of the major, there is a broad range of knowledge, abilities, predispositions and attitudes that we expect of a university graduate, collectively serving as the hallmark of higher education.

To help faculty understand about more about the issues surrounding GE, the Science Faculty themed this year's Teaching Workshop held on 20 April as "General Education Reform". A/P Chng Huang Hoon, Associate Provost (Undergraduate Education), was invited to share about the place of GE in a university curriculum. She spoke about the motivation, aims, challenges and hopes in articulating the new GE initiative and also the experience learnt from some overseas universities.

In NUS, a distributional approach has been adopted in initiating GE. Five themed pillars are devoted to general knowledge and transferrable skills: Singapore studies, thinking and expression, quantitative reasoning, human cultures and the question pillar. This structured GE curriculum occupies the university-level curriculum space, a university-level learning space allowing NUS students to have a full-fledged common university learning experience.

According to A/P Chng, the NUS GE is a curriculum block which aims to lay the basic foundation for important intellectual habits of mind such as analyses and appreciation of ideas and perspectives. It also includes the inculcation of the type of life skills that the new marketplace requires of all working adults and life-long learners, skills that many employers have identified as needing more active cultivation among our graduates.

This revised GE is guided by the key principles of providing an intellectual broadening outside the major or minor disciplines; allowing students to explore topics or issues that are of specific interest to them, and in the process take a step towards developing their curiosity and learning certain skills that can help them in their nus journey and beyond; granting an opportunity for student interaction with

peers from other subject majors; and giving nus students a common university experience.

A/P Phil Chan, who is chairman of the GE Committee, shared with faculty during the workshop his experience of teaching a GE module titled "Einstein's Universe and Quantum Weirdness". He explained how he approached his teaching with a historical and philosophical perspective besides a scientific one and also how his lessons were incorporated with real-life examples of scientific endeavours and applications.

The department also held a sharing cum discussion session on 15 May for lecturers and tutors concerned about the GE review. A/P Chan spoke further about the GE pillars and their key elements.

He reiterated that GE is about helping our students to become generalists, while the disciplinary majors are about producing specialists. GE is not an extension of the disciplinary majors; it is above the distinction between science and humanities and not meant to compensate students from their supposed lack of knowledge in any disciplinary domain. A/P Chung Keng Yeow also shared about his experience in mounting a new GE module titled "Radiation—What it is and How it Affects Our Lives".

Indeed, GE reform is underway and will always be for that is what life-long learning is about. Adopting a holistic approach to this aspect of the university education will certainly go a long way in impacting a new generation of young people with a greater sense of appreciation, adaptation and passion in life.

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↑ A/P Chng (centre) at Science Faculty's Teaching Workshop 2015



↑ GE review discussion in department



Public Talk at the ArtScience Museum, Marina Bay Sands

Contributed by Mr Tan Peng Kian, PhD student, CQT



Last year, my research group participated in Maker Faire Singapore, a show and tell event that is also international. A poster featuring my doctoral research in the measurement of photon bunching of sunlight in Singapore was displayed. This caught the eye of Ms Honor Harger, the Executive Director of the ArtScience Museum, MBS. She then invited me to give a talk for a “Visualising the Universe” event held last year.

The ArtScience museum held an exhibition on Leonardo da Vinci the first half of this year, featuring some of his original artefacts and writings. Concurrently, it also hosted a conference titled “Nurturing Leonardos” to share and showcase systems thinking in the local scene.

From the vantage point of a Singaporean physicist-wannabe, I spoke about my motivation and the methods I use to develop observational astronomy research in Singapore in view of our geographical disadvantages. The focus was neither on the math nor the equipment, but the human side of science, so as to relate to the art of creativity and innovation as a way of life, rather than simply the pursuit of scientific knowledge or the carving of a career.

The response from the audience was heartening. The audience, like the speakers, were from diverse background—scientists, artists, entrepreneurs, civil servants, students, working professionals and families, with a good mix of locals and foreigners.

After the public talk, I am more than ever convinced that imagination and curiosity may not be measured or quantified, but they really make all the difference.

Germany Immersion Trip (GIT) 2015

A total of 18 students from the Faculty of Science spent 3 weeks (8–28 June) in Munich and Göttingen for GIT 2015. It turned out to be an eventful and memorable trip for the students as they attended lectures and visited labs, museums, parks and many other interesting places.



↑ The Max Planck Institute, Göttingen



↑ TRINOs Vacuum Systems, Göttingen

↓ Olympic Park, München



From Freshman to Graduate: My Journey in NUS

My journey in NUS began some ten years ago—the year 2004. It seemed so far back that I could not recall why I went into physics. My secondary school physics teacher might have sparked that interest in me. As an undergraduate, I came to appreciate physics as a conceptual framework for making sense and predictions of the physical world around us. This partly motivated me to pursue my studies further upon graduation. One of the coolest things about being a practicing physicist is that you get a lot of opportunities to be empowered to understand the newest discoveries, ask sensible questions and actually have the toolkit to solve the mysteries yourself. There is always something new to discover every day.

Upon the completion of my master's programme, I found more options awaiting me. Being the practical guy, the PhD programme offered by the NUS Graduate School for Integrative Sciences and Engineering appealed to me. Though I was with the Department of Electrical and Computer Engineering till my graduation this year, I still headed back to the Science Faculty quite often as I was actively involved in the Special

Programme in Science. The former batches of undergraduates may probably remember me as the Mathematica guy.

I still consider the Physics Department my “spiritual” home. It has been a delightful place to me all these years. As an undergraduate, I got to know my course mates pretty well. We bonded over the common mishap of having to struggle over the use of equipment in two experimental modules, as well as the attendance of some quantum mechanics tutorials (without which it was just impossible to graduate)!

Now that I use quantum mechanics every day in my day-to-day work, I am immensely grateful to the solid foundation that I have received in the past. I also looked back at the days I worked as an undergraduate researcher in the current Nanomaterials Research Lab with wonder. This was where I learnt the art of playful enquiry.

I am thankful for many life-long friends whose paths crossed mine throughout my NUS days. Though I do not know what lies way ahead for me, but one thing for sure is that my journey from freshman to graduate is one I will remember for years to come.

Siu Zhuo Bin



Our Alumni Speak ...

Two alumni shared with *Physics Matters* how they are getting on in their lives and also the role a physics education has played in their present undertaking.

2014 was a happy year for me because finally I graduated! It was the moment I was waiting for—to do what I love most. Currently I work as an apprentice for a local artist. In the art studio, I get to create pop art style acrylic paintings. I also freelance as a portrait artist.

Since I was a kid, I have developed a strong liking for the visual arts. So why did I venture into physics? To be honest, I did not start out to be passionate about my studies. But physics somehow appealed to me because I found that I could score in most of the physics tests. That left me with time to pursue my other hobbies, in particular the arts.

I doubted if any professor took notice of me in the university since I was not one who asked questions and gave my full attention in class. But I think I became a smarter and more creative person in the process of studying (more like surviving) as a physics major!

To “think out of box” is very important in both physics and arts. It transforms you into a great physicist or artist. Physicists who process massive data must have the discipline too to extract, process and interpret important data. This process is very similar to creating a piece of drawing that has very technical details.

Creativity is always important in art. I often manage to propose a “different” idea or element to my boss or customers. Also, the knowledge I acquired in cosmology during university has helped carved an interesting and unique philosophical approach in my own art pieces.

I have chosen to be an artist. It's my passion and my dream. I'm joyful with what I am doing since drawing and painting are my hobbies and it's just fantastic to be doing them as a career.

Yang Chong Yi



intended.

When I was younger I thought it would be quite cool to be a scientist, and I seriously considered pursuing research as a career or perhaps working at the science centre. It was only after a teaching stint just before entering university that I realised I would love to teach, instead of do, science, as I enjoy working with youths. As Confucius taught, “Choose a job you love, and you will never have to work a day in your life.”

Frankly, one does not need quantum mechanics or an honours project to teach in secondary schools. I find myself in a dilemma whenever students ask me fundamental questions such as “Why does the first shell of an atom contain only two electrons, while the second shell eight? Why not four?” I would start thinking about the wavefunctions and energy eigenvalues that I struggled with in my QM modules, but realise that I am unable to bring them down to my students' level.

New friends I meet tend to go “Wow, you majored in Physics.” Indeed graduating as a Physics major in 2014 was no easy feat for me, even though I was studying what I long

It dawned on me that it is not about the content knowledge, but life skills such as thought processes, scientific inquiry and resilience that I have acquired as a physics major that I can impart to my students. For example, recently I had the opportunity to lead a team of students for a science project competition. My experience in various research projects in university actually came in handy as I guided my students in their preparation. Being a past physics major also enabled me to suggest and implement experiment-based lessons confidently since I am grounded in my subject matter.

Teaching, like campus life, could be hectic and demanding but I can testify that it is a ‘madness’ of its own kind. I miss the times when I could shut myself in the lab or be absorbed in some classical mechanics problem. Having to constantly account to my bosses, colleagues, students and parents means little time left for myself. Nonetheless, I am blessed to have much loving support from my friends and colleagues.

On a closing note, I would like to encourage our physics undergraduates to treasure your time as a student, and know that your university experience will shape and guard you in future as you step into the working world.

Jacqueline Lie





'Advocating' Physics

A/Prof Thomas Osipowicz shared a few remarks on the teaching and learning of physics.

How to organize, develop and (hopefully) improve the teaching of university-level physics at our department constitutes a major part of my work: Firstly with regard to my own teaching and secondly, in a more general way, concerning the physics curriculum development. I would like to say a few words on both topics.

As to the former (mainly regrading PC3246 Nuclear Astrophysics), well, this may be considered somewhat old-fashioned, but the main aim of my teaching is for students to learn the physics that constitutes the content of the course. The more modern additional objectives, namely the development of student's problem solving skills and critical thinking capabilities are certainly encouraged and nurtured, but I think this should be more or less a built-in feature, because classroom discussion and problem solving are a large part of the module. I have added features that were unavailable not long ago, eg the beautiful movies the European Space Agency

makes available on the topic of GAIA satellite mission, but I also think that straightforward classroom teaching still is the preferred mode of learning, at least in such a relatively high-level module.

As to curriculum development, we have just this year finalised a major review of the physics curriculum. One of the major changes is the introduction of a new essential level 2000 module, namely PC2134 Mathematical Methods in Physics I. This was considered necessary to help our students acquire the mathematics skills needed in many high-level modules. Furthermore, at our department, traditionally three essential quantum mechanics modules were required. We found that this is not the international norm. In nearly all leading universities worldwide only two quantum mechanics modules are essential requirements. We have decided to follow this practice in the future. In addition, the syllabi of many modules were refined and optimised in order to offer a more coherent and up-to-date physics curriculum.

Prof Sow Chorng Haur shared about the two talks he delivered at the National Taiwan University and the National Museum of Natural Sciences.

I received an invitation to deliver a talk from Prof Zhu Shiwei from the Department of Physics, National Taiwan University (NTU). As the associate director of the Center for Teaching and Learning Development (CTLD), NTU, Prof Zhu is also tasked with the design and implementation of programmes for the development of teachers. From time to time, CTLD invites professors from overseas to share their teaching experience and practices.

As Singapore is a country known for its science education, CTLD hopes to learn about the innovations of science education here. Hence I devoted my sharing to the wide variety of science outreach programmes we have developed in Singapore. The talk delivered on 5 June had about 100 participants, comprising mainly of professors, teachers and students. Educators and directors from other organisations including the Science Museum and National Museum were also present.

During my talk, I also introduced science demonstration intermittently to liven the atmosphere. In fact I had to book a flight to Taipei that would allow extra luggage weight since I had to check in another luggage containing some of the demonstration apparatus from our Science Demo Lab. The local organiser had also made preparations for some items I needed but unable to bring along; for example, liquid nitrogen, ice block with tissue paper and Wimshurst machine.

As the professors from NTU are aware of my strong interest and belief in teaching by incorporating demonstrations, we agreed that it would be appropriate

for me to deliver a public talk on science demonstrations. The talk on 7 June at the National Museum of Natural Sciences, Taichung, attracted about 80 visitors who were mainly families with young children, senior citizens, students and museum staff. The audience were spontaneous and full of energy and it was a simply fun-filled session.

Whether it was to share innovating outreach ideas or promote physics in a lively way, both talks had been a great experience for me.



↑ Promotional flyer of the talk



← Prof Sow giving talks at the National Taiwan University and the National Museum of Natural Sciences



Discovering Physics:

Spherical photon orbits around a rotating black hole

When one talks about making a discovery in physics, more often than not one thinks of coming up with a new theory, or detecting a new fundamental particle. Usually a discovery stems from having a noble intention in mind: to push back the frontiers of knowledge, or to create something useful to mankind. Indeed, much of my research has been driven by this (primarily the former, since I am a theoretical physicist). But occasionally, I feel the urge to work on a physics problem purely for the fun of it.

Whenever I feel this way, I like to browse through the pages of the *American Journal of Physics*. Unlike regular physics journals, this one is targeted specifically at university teachers and students, and often contains interesting physics problems and their solutions. It was one day in the late 1990's, when I was browsing through this journal, that I stumbled upon the paper [1]. It was primarily on how the night sky would appear in the vicinity of a rotating black hole, but at the end of the paper, there were a few diagrams of how photons can orbit around such a black hole, essentially forever. These were three-dimensional orbits of constant radius—not necessarily confined to the equatorial plane—and I was fascinated by them.

Since the paper provided scant details on how these orbits were derived, I went to think about them. What started off as a “fun” problem became a medium-term research project: I read background papers, did calculations, and wrote a computer program to plot these orbits out. I even got a student to work on it as a UROPS project. Eventually, I succeeded in obtaining the equations governing such “spherical” photon orbits, and worked out their properties. Using the computer program I wrote, I then plotted out examples of these orbits.

The plots that appeared before my eyes were totally mesmerising. All the long calculations and complicated equations could not prepare me for the beautiful and intricate structure of these plots. Many of them resembled woven baskets (Figs. 1 and 2); while others the seams on a tennis ball (Fig. 3). In each of these orbits, the photon travels between some maximum and minimum latitude. The orbit in Fig. 3 is special in that it actually reaches the north and south poles. In this case, the photons have zero angular momentum; they orbit around the black hole due to the dragging of space-time by the latter.

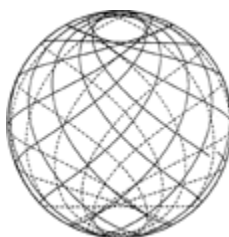


Fig. 1

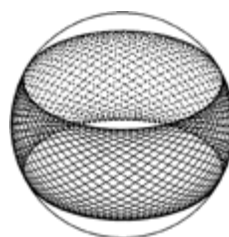


Fig. 2

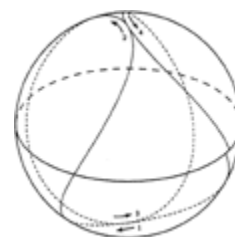


Fig. 3

In 2003, I wrapped this project up with the publication of the paper [2], and supplemented it with a website (<http://www.physics.nus.edu.sg/~phyteoe/kerr/>) containing more examples of these spherical photon orbits. It was a satisfying end to the project. To me, these orbits showed how beautiful physics can be, even though there was almost no chance of observing them in nature.

Little could I have imagined that more than a decade later, this work would find its way into a major Hollywood movie. Kip Thorne, the well-known theoretical physicist and scientific advisor of the movie *Interstellar*, referred to these spherical photon orbits collectively as the “shell of fire” [3]. He then used it as a basis to visualise the black hole Gargantua in this movie; the resulting images are possibly the most accurate rendering of a rotating black hole ever produced. Not a bad outcome, for what started off as just a fun project...

References

- [1] J Schastok et al, “Stellar sky as seen from the vicinity of a black hole”, *American Journal of Physics* **55** (1987) 336.
- [2] E Teo, “Spherical photon orbits around a Kerr black hole”, *General Relativity and Gravitation* **35** (2003) 1909.
- [3] K. Thorne, “The science of *Interstellar*”, W W Norton, NY, 2014.



A/Prof Edward Teo received his PhD from the University of Cambridge in 1994. He joined the Physics Department of NUS in 1997, where he is presently an Associate Professor. His research lies in the field of General Relativity and Gravitation, in particular, the subject of black holes.

Awards

Congratulations to our colleagues in the department for being the proud recipients of various awards in the year 2015!

Annual Teaching Excellence Award

A/P Chan Aik Hui, Phil

A/P Kuldip Singh

Dr Chammika N B Udalgama

Dr Yeo Ye

NUS Young Researcher Award

Asst/P Goki Eda

NUS High School Inspiring Research Mentor Award

Dr M V Venkatasamy Reddy

Dr Png Rui Qi

IPS President Medal

Prof Oh Choo Hiap

IPS-Cadi Scientific Medal for Public Awareness of Physics

Prof B V R Chowdari

Best Wishes

The department likes to thank Prof Li Baowen for all his contributions during his stay and wishes him all the best in his next undertaking.

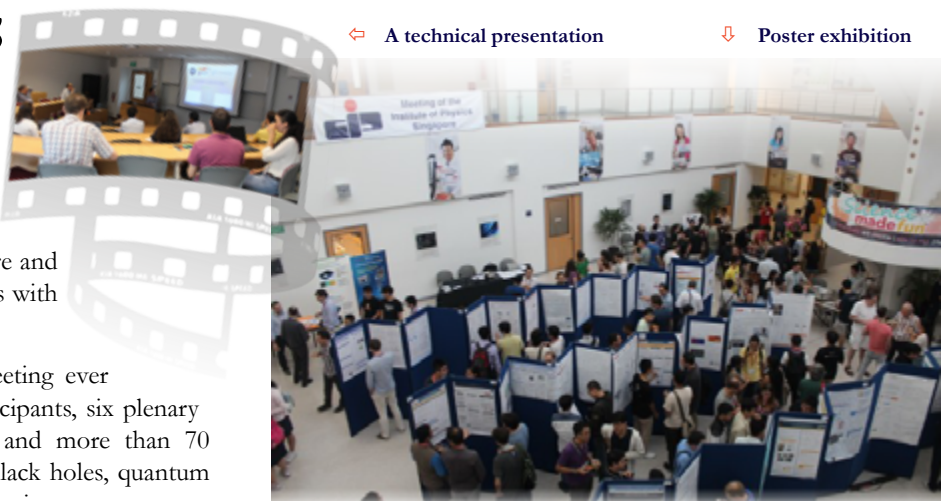


IPS Meeting 2015

The Institute of Physics Singapore (IPS) Meeting 2015 was held from 4 to 6 Mar at the School of Physical and Mathematical Sciences, Nanyang Technological University. The meeting serves to connect physicists active in research across Singapore and to allow the sharing of the latest discoveries with fellow scientists.

This year also marked the largest IPS meeting ever since its inauguration, with about 300 participants, six plenary sessions, over 95 technical presentations and more than 70 posters. The range of topics varied from black holes, quantum metrology, 2D materials, photonics to biophysics.

 A technical presentation


 Poster exhibition


Visits by Foreign Student Delegates

Three groups of foreign student delegates visited the department in the months of April, May and July. They were from the University of Groningen, Zhejiang University and the East China University of Science and Technology.

Besides attending briefing and talks, the delegates also visited research labs and witnessed some interesting first-hand physics demonstrations.



 At the Centre for Advanced 2D Materials



 At a demo session

 At the Centre for Quantum Technologies



A Day in the Life of...



There is a quiet disposition and modesty about Mr Ali bin Haji Omar, also known as Ali, that none of those who know him would deny. Having more than 40 years of service with the university, Ali takes his daily duties in his stride. The operations associate could still recall his work at the former School of Accountancy at the Bukit Timah campus way back in the 1970s. Those were the days when cyclostyle machines were heavily used for printing. He did not regret asking for a transfer to the Science Faculty when the school moved out.

A day in the life of Ali in the Physics Department involved quite a bit of walking around campus. He makes sure all the internal dispatching of mails and parcels, big or small, are delivered promptly. Mails that required hand delivery will take longer time as the destination could be at the other end of campus. He also has to make trips to an off-campus post office whenever there is request for sending of registered mail.

Ali sees to the upkeep of the conference room as well as CIBA lab. He makes sure refreshments are on the conference room table before seminars and meetings begin. He also helps in office work

such as binding manuals, printing documents and making sure the office back door is securely locked on a daily basis.

Indeed no task is too mundane for Ali. When asked if he liked working in the department, Ali's answer was an absolute "very much"! Ali added, "Here, I get to do useful things. I see my colleagues and talk to them. Life would be boring without work." Indeed, Ali appreciates his working environment and colleagues around. He enjoys looking especially at the green scenery (field) next to the physics buildings. To him, even a momentary stare at the field offers a relaxation to his eyes.

Ali has always been an active sportsman since his Bukit Timah campus days. He recalled having participated in friendly matches between statutory boards back then. Even in recent years, he never failed to join in the interdepartmental games organised by the Faculty of Science. He likes soccer and bowling in particular.

Ali hopes to stay active physically. To him, being happy is a state of the mind. He believes even if life circumstances turn unfavourable, it is always important to stay optimistic.



Events by Physoc

Various talks, bonding and outreach activities were organised in the first half of 2015 with the help from the NUS Physics Society. Here are some photos that captured these precious moments.



⇒ 'Physics & Beyond' by Dr Yeo Ye, 11 Feb

⇒ Physics Enrichment Camp, 8 – 11 Jun

⇒ Chinese New Year Celebration, 16 Feb



⇒ Physics Orientation Camp, 6 – 8 Jul



⇒ Crystal Structure Workshop by Prof Sow Chong Haur, 18 Mar



Sigma Pi Sigma Induction Ceremony

The NUS Sigma Pi Sigma ($\Sigma\Pi\Sigma$) induction ceremony was held on 9 July with 12 new members welcomed into the fellowship. $\Sigma\Pi\Sigma$ is an American physics honour society founded in 1921, and the NUS $\Sigma\Pi\Sigma$ Chapter was chartered in 2011. $\Sigma\Pi\Sigma$ exists to provide a fellowship of persons who have excelled in physics.

Departmental Staff Outing

Staff truly enjoyed the two events organised by the departmental Welfare Committee. They were the lunch cum bowling session on 23 Feb and lunch cum River Safari tour on 28 July. Take a walk down memory lane with these photos.



Congratulations Class of 2015!

Bachelor of Science

Arwinder Singh
Chang Yu Ping
Chen Yisheng Jonathan (SPS)
Chia Xiang Min Stacey
Chow Shang Xuan Cliff
Gayatri d/o Aruchunan
Goh Kok Hoe Octave
Goh Sor Ee Lloyd
Muhammad Azhar B Rahyiu
Neo Jack Wee
Putri Wahyu Desyani
See Ai Xin
Sidharth Krishnan
Willis Lim Qi Han

Double Degree Program

Loke Zi Jie Gabriel

Doctor of Philosophy

Amar Srivastava
Bai Zhaoqiang
Ching Chee Leong
Chintalapati Sandhya
Dagmawi Belaineh
Du Xin
Durgarao Guttula
Guo Han
Han Cheng
Kadir Durak
Law Zhiyang
Lin Jia Dan
Liu Fan
Luo Yuan
Luo Ziyu
Pawan Kumar
Teguh Citra Asmara (Materials Research Society of Singapore Medal)
Wang Rui
Wu Fei
Wu Jianfeng
Wu Qingyun
Xiong Boqian
Yang Lina
Yao Yong
Yap Tiong Leh
Yin Xinmao
Zeng Shengwei
Zhang Jialin
Zhao Qifang
Zheng Minrui
Zhong Jianqiang

Bachelor of Science with Honours

Alpin Novianus Tatan
Ang Jian Martin
Chai Jing Hao (USP scholar)
Chew Boon Kiat
Chiang Yi Herng
Daniel Tan Ke Jun
Evan Laksono (SPS)
Ho Jin Qing
Ho Yen Kuang Kennison
Ho Yi Wei
Huan Jia Yan
Jazreel Zhou Jun
Jufri Setianegara
Kelvin Horia
Koh Zhi Xun
Kong Ching Wan
Kwang Siu Yi (SPS)
Lee Joon Hon Alvin
Li Jiayu
Lim Fu Kang
Lim Rong Sheng
Lim Yong Hui (USP scholar)
Michel Lim Yi Han (USP scholar)
Mu Sen
Ng Kia Boon (IPS Medal, Lijen Industrial Development Medal, Jurong Shipyard Prize, SPS)

Master of Science

Arifin
Chen Chang Pang
Chen Qingqing
Chen Zimei
Cheng Kok Cheong
Feng Shixiao
Gao Meng
Gu Junqing
Ho Yuda
Huang Wanjing
Lee Chern Hui
Lin Yiteng
Miao Taonan
Qu Yujie
Raymond Santoso
Sandoko Kosen
Shen Lijiong
Uma Subramaniam
Ushnish Chaudhuri
Wang Boyu
Wang Guan
Wu Yue
Xu Ke
Xu Zhe
Zhang Meini
Zhang Xiuqi

Nguyen Dang Thien
Ooi Ching Pin (SPS)
Oon Zhi Jian Kevin
Pang Rudy
Phua Hao Yu (SPS)
Png Zhong Ting
Sim Jun Yan
Soh Rong'En (NUS Overseas College Programme, SPS)
Tan Ying Zhe Ernest (NUSS Medal for Outstanding Achievement, Jurong Shipyard Prize, Sugar Industry of Singapore Book Prize, SPS)
Tang Wenjie Shawn (SPS)
Tang Zong Sheng (SPS)
Tham Yap Fung
Wang Xiande Samuel
Wen Borui (SPS)
Wong Whye Khuin Nicholas (Jurong Shipyard Prize, USP scholar)
Woo Jia Qian
Wu Di
Wu Shuang
Yasmin Yeow
Ye Yong'En Joash
Yeo Qing Yuan
Zhao Chuyuan
Zhou Yifan

