A Proposal to Establish a Centre for Nurturing Computing Excellence

Daren Ler, Steven Halim, Tan Sun Teck

Revised 29 July 2022

A. Vision Statement

The Centre for Nurturing Computing Excellence (CeNCE) is a learning space where university faculty and staff, students and teachers from various levels, and other stakeholders work collaboratively to create rich and engaging teaching and learning experiences that focus on nurturing the discipline of computing. By offering students various core pathways within computing, the centre seeks to instil core computing competencies in all students interested in the field, and to identify and nurture talented students. The centre will do so by fostering vital community partnerships and growing an intellectually diverse fraternity that practices active and life-long learning.

B. Introduction and Motivation

Over the past several years, we have worked conscientiously to host the 2020 International Olympiad in Informatics (IOI). Unfazed by the emergence of COVID-19, we went on to successfully hosted not one, but two online IOIs in September 2020 and June 2021. During the IOI 2021 competition, we also achieved Singapore's best result since our first participation in 1992, with a haul of 3 Gold Medals and 1 Silver Medal. This achievement has been years in the making, and has required significant innovation, expertise, and grit. However, despite this amazing result, we have observed that there remains a potential for significant growth. The team that achieved our record result was comprised of (8) talented students from only 2 schools, namely NUS High School of Mathematics and Science (NUSH) and Hwa Chong Institution (HCI). Traditionally, there has also been representation from Raffles Institution (RI). The largely homogeneous pool of representatives is, at least partially, due to the limited computing and competitive programming (CP) resources that the other schools have at their disposal.

This observation was reinforced by the results for this year's Qualification Contest for the National Olympiad in Informatics (NOI), which was held on 19 February 2022. The contest attracted a record 519 participants from 37 Secondary Schools and 23 Junior Colleges. However, only 163 students (about 31%) managed non-zero scores. Among those, only 85 (about 16%) scored more than 20 out of 300 marks. 19 of the top 20 contestants were all from the three schools previously mentioned (i.e., NUSH, HCI, and RI). These statistics clearly indicate that many students who are interested in computing and CP contests do not have access to effective training and resources.

By affording more opportunities for other schools to access the relevant resources, the breadth and depth of the talent pool will be enhanced. This would in turn increase our chances of being able to mimic the achievements of countries such as China, Russia, and the United States of America, where a 4-Gold haul is the norm.

While the above is an important and primary objective, it is not CeNCE's only focus. Many students do not possess the attitude and aptitude necessary for CP at the highest levels. However, all students should be able to benefit from a computational thinking perspective. This is evidenced by the growing emphasis being placed on the inclusion of computing within general pre-tertiary (K-12) education. For instance, PISA has recently begun to incorporate computational thinking within its mathematics assessment [4]. A recent study by UNESCO [6] further highlights the growing importance of incorporating an AI curriculum into K-12 education, which includes teaching computing fundamentals.

Consequently, the centre's secondary objective will be to raise the computing literacy of our general student population by offering fundamental computational thinking instruction in a modular fashion, with additional options to branch into other computer science specialisations, including Artificial Intelligence (AI) and Data Science (DS), Web Application Development (Web App) and Internet of Things (IoT), and Financial Technology (FinTech). Such pathways will further be supported by industry collaborations, which we have already established. For example, Blockchain training with Tezos APAC, Data Science with Micron, and AI and Networking with Huawei. These proposed curriculums and pathways are depicted in Figure 1 below.

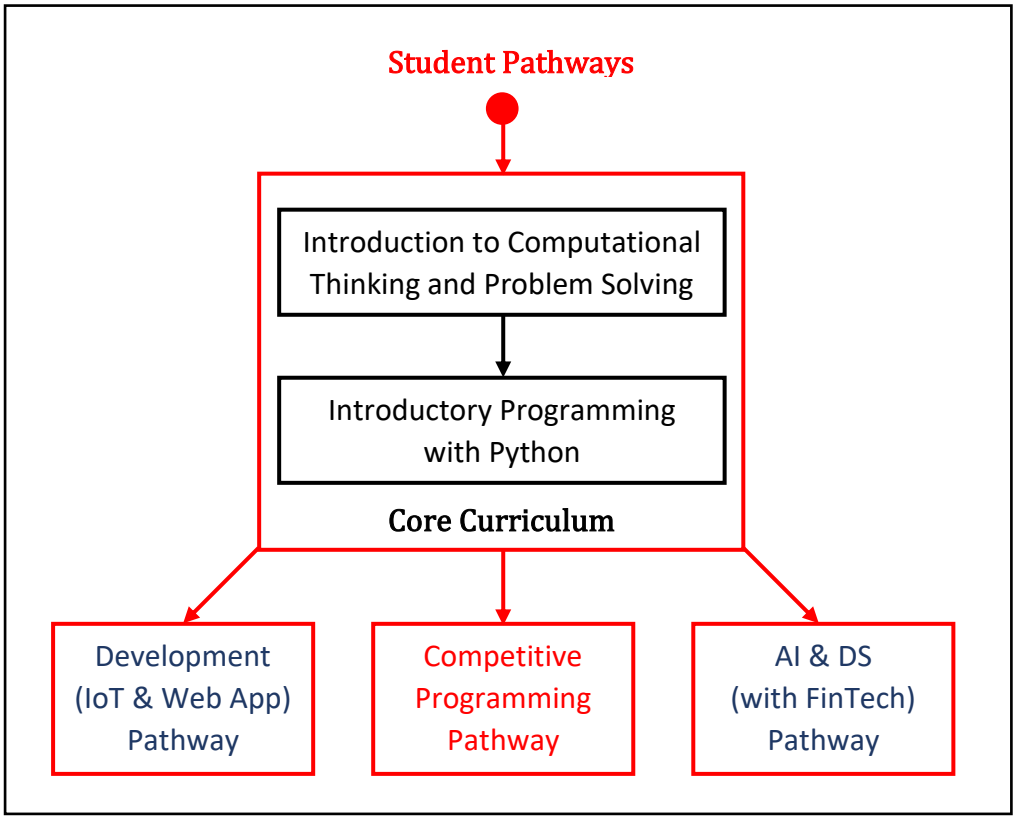

Figure 1. The proposed student pathways stemming from a common core.

CeNCE will initially focus on the Core Curriculum and the Competitive Programming Pathway (CP Pathway), with the other proposed pathways will be developed in time.

It is our belief that this proposed modular curriculum, driven by input and expertise from our industry partners, would play a vital part within a virtuous cycle that enriches both Singapore's pool of computationally literate manpower, and the capacity of the Tech

Industry in Singapore, which is in alignment with many other initiatives in Singapore, including the Smart Nation initiative [5].

Finally, we must face the realities of computing education: there is a global shortage of skilled computing professionals, as evidenced by the recent letter penned by over 500 business, education, and non-profit leaders in the United States of America [1], as well as in local reports – e.g., in [3]. This shortage, if left unchecked, will perpetrate a vicious cycle where few with the necessary proficiencies become computing teachers, which in turn potentially results in relatively fewer students being trained to meet the demands of society, let alone further grow the ranks of trained computing teachers.

As a longer-term objective CeNCE may also serve to ease this problem by conducting computing teacher conversion programmes for pre-tertiary teachers. Essentially, we could do this by tapping upon the existing system of utilising undergraduate and postgraduate teaching assistants.

Ultimately, we believe that the success of the pathways will largely depend on the willingness of teachers to encourage their students to particulate and use the centre's resources. Additionally affording interested teachers an opportunity to upskill and gain certification should, in turn, improve the likelihood of achieving our objectives. By improving computing capabilities of teachers, we would counter the vicious cycle and replace it with a virtuous one where the teachers would in turn cultivate more computationally savvy students and improve the profile of those teachers.

The remainder of this proposal will describe the proposed organisational structure of CeNCE, as well as elaborate on the CP Pathway.

C. Organisational Structure

The proposed organisational structure of CeNCE is depicted in Figure 2.

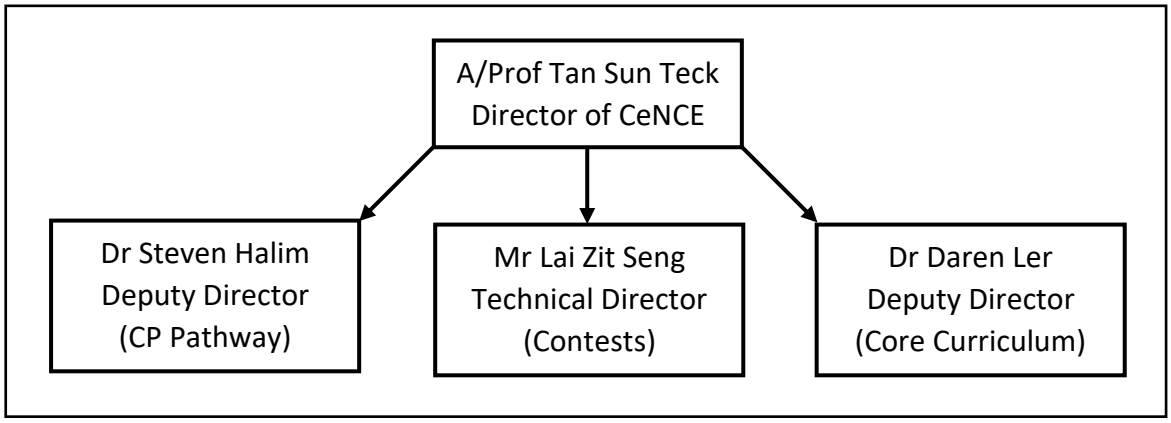

Figure 2. The proposed organisational structure of CeNCE.

CeNCE will be led by Associate Professor Tan Sun Teck, who will serve as the centre's director. He has served as the Executive Director of the Organising Committee for both IOI 2020 and IOI 2021 and has been conducting the training for local secondary/JC students to prepare them for NOI and IOI for the past 12 years.

Dr Steven Halim and Dr Daren Ler will serve as the Deputy Directors of the centre. Dr Halim will oversee the modules under the CP Pathway, while Dr Ler will oversee the modules under the Core Curriculum.

Dr Steven is a Senior Lecturer at SOC who served as the Deputy Director of the Organising Committee for IOI 2020 and IOI 2021, as well as the Regional Contest Directory for the International Collegiate Programming Contest (ICPC). He is also a co-author of Competitive Programming 4 textbook.

Dr Ler is a Lecturer at SOC who served as a Member of the Organising Committee for both IOI 2020 and IOI 2021 and has also served as the Honorary Secretary of the National Olympiad in Informatics in Singapore since 2020. Upon receiving his Postgraduate Diploma in Education (PGDE) in 2015, he served as a H2 Computing teacher at National Junior College until the end of 2019. There he also served as the facilitator of both the H2 Computing Network Learning Community (NLC) and Instructional Programme Support Group (IPSG).

The centre will also be supported by Mr Lai Zit Seng, a Senior IT Architect at SOC. Zit Seng was on the Technical Committee for both IOI 2020, IOI 2021, and IOI 2022. He will serve as the Technical Director of CeNCE, who will supervise all technical matters around the contests that will be conducted.

D. The Competitive Programming Pathway

The primary objective of CeNCE is to develop a robust system that will ensure Singapore's continued success at the International Olympiad in Informatics. This not only involves training students for Informatics Olympiad Competitions, but also organising and running such competitions.

There are four annual competitions that are relevant.

- The National Olympiad in Informatics (NOI)
- The Asia-Pacific Informatics Olympiad (APIO)
- The European Girls' Olympiad in Informatics (EGOI)
- The International Olympiad in Informatics (IOI)

The existing timeline for the system currently in place is depicted in Figure 3.

The selection of the IOI Team is based on the results of two competitions, NOI and APIO. As places are limited for APIO, only those performing very well at NOI are invited to participate in APIO (i.e., only gold medallists and high-scoring silver medallists). A weighted (typically linear) aggregation of these two scores is used as the overall selection criteria for the IOI Team.

To ensure that selected students approach their optimal potential, training is conducted throughout the process. Further, to seed the cohort, general training workshops are conducted during the December holidays. Schools are invited to send a limited number of students to attend these workshops, which cater to both beginner and intermediate levels.

The proposed CP Pathway will replace the current training programme conducted during the December holidays (denoted NOI Training in Figure 3). This change will better support the students interested in computing by providing a robust curriculum to teach them computational thinking and programming fundamentals, and then extend this knowledge with more competitive programming training. In doing so, we will also be offering students opportunities to pursue the additional pathways depicted in Figure 1.

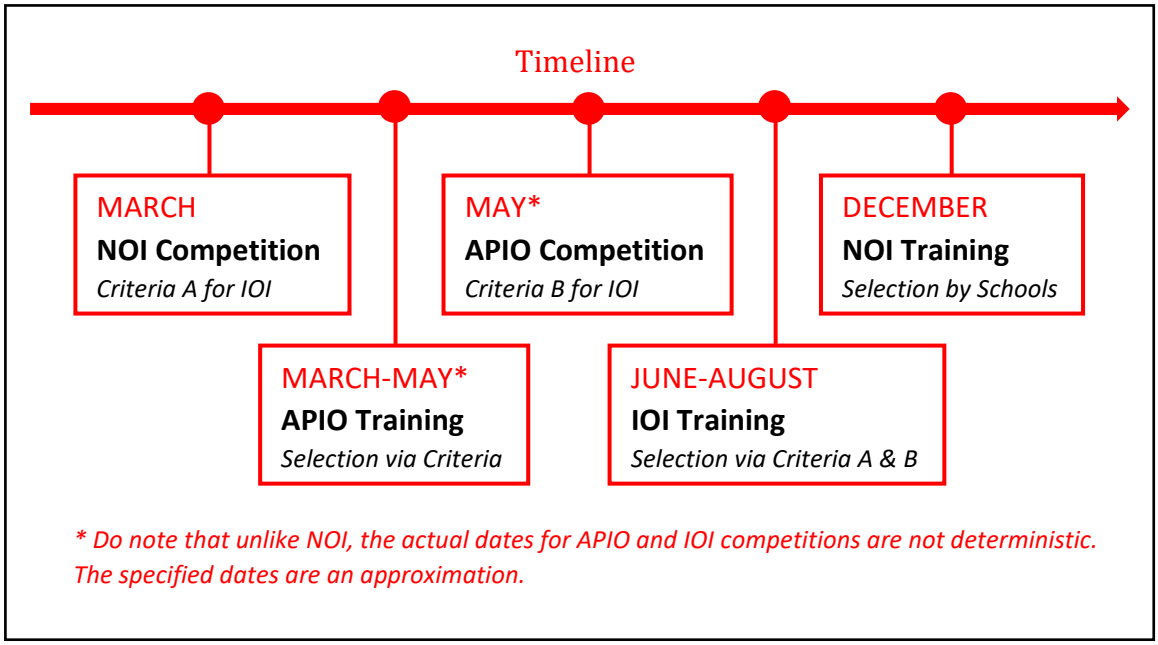

Figure 3. The current timeline for Informatics Olympiad training.

More specifically, the proposed modules under the CP Pathway are depicted in Figure 4. The details of each module are further elaborated in Table 1.

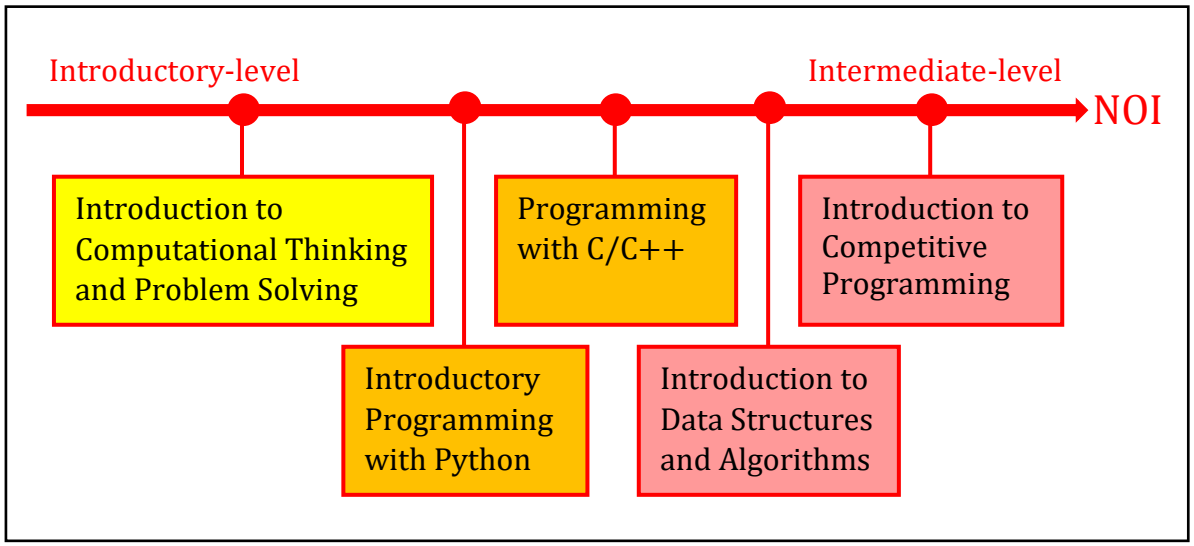

Figure 4. The proposed modules under the competitive programming pathway.

This modular design allows students to participate in any module within the sequence. To motivate the students, we further proposed that each module be paired with an associated competition, which further serves as a qualification assessment. Only students who exceed a certain threshold will be allowed to participate in a more intermediate

module. By looking at past competitions, both teachers and students can easily determine the right training they should seek, and thereafter continue along the pathway if they so choose.

Module	Description

Introduction to Computational Thinking and Problem Solving	• Introduces computational thinking (CT) as problem-solving
	  ○ Focuses on Polya's Problem-solving Process (PPSP)
	  ○ Emphasis on problem formulation and basic representations
	  ○ Leverages CT ideas – e.g., solutions via search/optimisation (AI)
	  ○ Emphasis on problem-solving as separate to implementation
	  ○ Entirely syntax agnostic - code examples in multiple languages
	• Motivated by current curriculum development at SOC PLC
	  ○ Ideas based on GET1031, CS1010, CS1010E, and CS1010S
	• Theory-based, examination-style competition

Introductory Programming with Python	• Consolidates problem-solving by focusing on implementation
	  ○ Introduces Python syntax
	  ○ Translating problem solutions to code
	  ○ Begin to focus on complexity and practical efficiencies
	  ○ Mastery of software development tools and skills
	• Content from CS1010E and CS1010S
	• Practical-based examination-style competition

Programming with C/C++	• Extending student knowledge to include explicit memory management
	  ○ Introduces C/C++ syntax
	  ○ Emphasis on memory management
	  ○ Even greater focus on complexity and practical efficiencies
	• Content from CS1010
	• Practical-based, examination-style competition

Introduction to Data Structures and Algorithms	• Adding building blocks for problem solving
	  ○ Introduces fundamental Data Structures and Algorithms
	  ○ Time and space complexities are now an integral part of problem solving
	  ○ Using the latest C++ standard and libraries
	• Content from CS2040C
	• Practical-based, examination-style competition

Introduction to Competitive Programming	• Preparing students for actual informatics competitions
	  ○ Introduces more advanced algorithmic problem-solving techniques
	  ○ Introduces competitive problem solving under time pressure
	  ○ Gaining experience via weekly mini competitions
	• Content from (the first half of) CS3233
	  ○ To be conducted from January to early March each year before NOI
	• Competitive programming competition

Table 1. A summary of the modules under CeNCE's CP Pathway.

It should be noted that with the exception of the Introduction to Competitive Programming modules, all proposed competitions associated with the other modules will largely be similar to written or practical examinations.

The learning objectives of each module are designed such that there are benefits to the students even if that module is read in isolation (i.e., not as part of the entire pathway). For example, on completion of the first module, Introduction to Computational Thinking and Problem Solving, students would be equipped with computational perspectives that augment their general problem-solving knowledge.

As advised, a separate programmatic application for funding has been submitted for the CP Pathway and its associated competitions [2]. For the time being, the funding for each of the four Olympiads (i.e., NOI, APIO, EGOI, and IOI) will also be made separately on an annual basis.

With this proposal, we seek MOE's endorsement for the establishment of CeNCE.

E. Conclusion

This application is motivated by the gaps that exist within the Singapore educational system related to Computing. While many resources exist to teach various topics in Computer Science, it is difficult for a student to adequately navigate this myriad of typically disassociated, and inappropriately calibrated material such that they would be able to glean the necessary information to make learning effective.

Our proposal effectively serves two purposes. Firstly, it allows us to cultivate a more robust system that will grow the population of students interested in competitive programming, as well as improve their overall quality with respect to Informatics Olympiads. Secondly, it will serve as a stop gap measure that would facilitate general computing proficiency within our school system.

We thank you for your time and consideration and look forward to a favourable response.

F. References

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