

CDIO FOR EDUCATION FOR SUSTAINABLE DEVELOPMENT USING COMMON CORE CURRICULUM

Sin-Moh CHEAH

School of Chemical & Life Sciences, Singapore Polytechnic

Lee Yee LIM

School of Life Skills & Communication, Singapore Polytechnic

Yunn Chyi CHAO

School of Mathematics & Science, Singapore Polytechnic

ABSTRACT

This paper describes an approach to integrate sustainable development into a program's curriculum using the CDIO Framework, with particular reference to the United Nations Sustainable Development Goals (UN SDGs). It proposes a set of guidance notes as "addendum" to the 12 CDIO Core Standards to provide further guidance towards how each Standard can be interpreted in all aspects of teaching and learning, from the learning context and learning outcomes, to integrated curriculum and various integrated learning experiences to learning assessment and program evaluation; as well as faculty professional development. This work is the direct outcome of a recent initiative in Singapore Polytechnic (SP) aimed at developing baseline emerging digital and human skills in students via a set of Common Core Curriculum (CCC). The CCC team works with all diplomas in SP to integrate these baseline emerging digital and human skills into their curriculum, using the UN SDGs as the learning context, where these skills will be deepened or applied in the domain modules. This paper firstly provides a brief overview of how CDIO had been used by the community to include the teaching of sustainable development, the state of involvement of higher educational institutes in providing education for sustainable development (ESD) in its programs. This paper also provides a short account on recent thinking about how best to deliver ESD for transformational learning; which is based on 2 key perspectives: that of behavioural change and empowerment of learners. The paper then explains what CCC is, in the context of educational landscape in Singapore, its key features and the integrated approach to the design and rollout of the CCC in Singapore Polytechnic. Next is the standard-by-standard explanation on how each standard can be interpreted through the lens of sustainable development, to provide guidance on how each can be used to support ESD. This is followed by a sharing of learning points from the recent pilot run of this approach and concludes with ideas of moving ahead in this endeavour to include ESD institution wide.

KEYWORDS

Common Core, Sustainable Development, CDIO Optional Standard 1, CDIO Core Standards 1, 2, 3, 7 and 12

NOTE: Singapore Polytechnic uses the word 'courses' to describe its education 'programs'. A 'course' in the Diploma in Chemical Engineering consists of many subjects that are termed 'modules'; which in the universities contexts are often called 'courses'. A teaching academic is known as a 'lecturer', which is often referred to as 'faculty' in the universities.

INTRODUCTION: THE CDIO FRAMEWORK AND SUSTAINABLE DEVELOPMENT

Various authors in the CDIO community had written on their efforts in using the CDIO Framework to address challenges related to sustainable development. For example, Borge, et al (2017) reported on their work that added sustainability to the INGENIA "Product Development" course at Universidad Politécnica de Madrid. Later Uruburu, et al (2018) updated on the work done with a review of the initiative after 3 years and wrote on the challenge faced in contextualizing each INGENIA project so that sustainability is not perceived as something separate or without connection to the project to be developed. Earlier, Hussman, Trandum & Vigild (2010) wrote on the use of "Green Challenge" at the Technical University of Denmark to include sustainability in engineering education. The first author and colleagues also wrote extensively on sustainable development in the context of Diploma in Chemical Engineering in Singapore Polytechnic (SP), see for example Cheah (2021), Cheah (2014), Yang & Cheah (2014), Chua & Cheah (2013).

CDIO formally introduced Sustainable Development as one of its optional standards in 2020 (Malmqvist, et al, 2020), after the proposal was first surfaced in 2007 (Malmqvist, Edstrom & Hugo, 2017). Also well under way (at the time of this paper) to also release an update to the CDIO syllabus to capture skills and attitudes needed to support sustainable development. Earlier Rosen, et al (2019) had reported on their effort to map the CDIO syllabus to the UNESCO key competencies for sustainability. Their studies concluded that the CDIO Syllabus is rather well aligned with the UNESCO framework, however several opportunities for strengthening the Syllabus in relation to the key competencies are identified.

This paper shares an institution-wide effort in SP aimed at integrating sustainable development, in a phased approach, into all diplomas offered by the institution. This will be achieved via a set of modules that made up a Common Core Curriculum (CCC) for integration into all diplomas. The work reported here is derived from the collective experiences of the authors, based on a pilot run with 2 diplomas. Specifically, it aims to provide guidance how curriculum redesign for the teaching of sustainable development can be carried out for adoption by other diplomas in SP, as well as for the wider CDIO community.

HIGHER EDUCATION AND EDUCATION FOR SUSTAINABLE DEVELOPMENT

According to the United Nations, education for sustainable development (ESD), also called education for sustainability (EfS) in some parts of the world, is a key concept for education in the new millennium. ESD is a broad concept bringing a distinctive orientation to many important aspects of education on the whole, including access, relevance, equity and inclusivity. Thus, ESD is far more than teaching knowledge and principles related to sustainability. ESD, in its broadest sense, is education for social transformation with the goal of creating more sustainable societies. ESD touches every aspect of education including planning, policy development, programme implementation, finance, curricula, teaching, learning, assessment, administration. ESD aims to provide a coherent interaction between

education, public awareness, and training with a view to creating a more sustainable future (UNESCO, 2012).

ESD empowers learners of all ages with the knowledge, skills, values and attitudes to address the interconnected global challenges we are facing, including climate change, environmental degradation, loss of biodiversity, poverty and inequality. Learning must therefore prepare students and learners of all ages to find solutions for the challenges of today and the future. Education should be transformative and allow us to make informed decisions and take individual and collective action to change our societies and care for the planet.

In recent years, higher education institutions are beginning to make more systemic changes towards ESD by re-orienting their education, research, operations and community outreach activities. However, despite the progress made and some signs of transition in parts of the academic community, there is still a long way to go to mainstream sustainability in higher education, and a paradigm shift from unsustainability to sustainability is still difficult to identify (Wals, 2014). Waas, et al (2011) opined that after more than two decades of debating and implementing sustainable development, to overcome arbitrary interpretations and reinforce the concept's action-guiding power, a better understanding of sustainable development and its implications for decision-making and policy-making is still needed.

More recently, Finnveden, et al (2020) reported on an interesting effort aimed at evaluating efforts in integrating sustainable development in higher education institutions (HEIs) in Sweden. The authors shared the findings commissioned by the Swedish higher education authority on behalf of the Swedish Government in 2016 to ascertain the progress of implementation after 10 years of following the introduction of the Swedish Higher Education Act in 2016, which mandated that all HEIs promote sustainable development in their programs. The study is unique in that all 47 HEIs in Sweden were involved, using a panel consisting of academics, students and working adults. Each institution is to complete a self-evaluation report consisting of 3 aspects: (1) Governance and organization, (2) Environment, Resources and areas, and (3) Design, implementation and outcomes; with 9 evaluation criteria. The panel studied each report and wrote its own evaluation report for each institution. The findings showed a mixed picture, in that while HEIs could give examples of programs or courses where SD was integrated, less than half of them had overarching goals for integration of sustainable development in education or had a systematic follow-up of these goals. Even fewer worked specifically with pedagogy and didactics, teaching and learning methods and environments, sustainability competencies or other characters of ESD.

CURRENT THINKING ON EDUCATION FOR SUSTAINABLE DEVELOPMENT

The approach of ESD seeks to empower learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society for present and future generations. It asks for an action-oriented, transformative pedagogy, which supports self-directed learning, participation and collaboration, problem-orientation, inter- and trans-disciplinarity and the linking of formal and informal learning (UNESCO, 2017).

Several authors had called for a new paradigm towards ESD, e.g. Barth & Michelsen (2013), Sterling (2010), Vare & Scott (2007). Sterling (2010) for example suggested a transformative education paradigm which he termed "sustainable education" which nurtures *resilient learners* able to develop *resilient social-ecological systems* in the face of a future of threat, uncertainty and surprise. An excellent summary on ESD was provided by Barth & Michelsen (2013), noting

that it deals explicitly with values and separates itself from a point of view that sees the act of learning as a neutral process and learning as a self-evident good (Sterling 2010). ESD therefore takes the position between the two poles of indoctrination and value-relativism: at one end, education is seen as a tool to achieve certain social goals, hence is criticized and rejected as an inappropriate way of instrumentalizing education for political ends. At the other end, the nature and purpose of education is stressed as being always determined by human values, history, and changing patterns of power relationships. It can never be value-neutral, as the processes of education continually expose students to filtered experiences (Fien 1997; Grant and Zeichner 1984). ESD should be one that considers learners' underlying values and support the learner's critical reflection on them.

Such an outcome can be represented by Figure 1, adapted from the works of Læssøe, et al, (2009), reported in Disterheft, et al (2013). As can be seen, the approach is made up of 2 perspectives: (1) one on empowerment perspective that focuses on enabling students to become independent critical thinkers; and (2) the other on behaviour modification perspective that strives for changes in habits. Through such learning, young individuals will develop the abilities to make sound choices in the face of the inherent complexity and uncertainty of the future; and become active participants in building more sustainable societies, able to tackle real and relevant social problems. As noted by Vare & Scott (2007), long term future will depend less on our compliance in being trained to do the 'right' thing now, and more on our capability to analyse, to question alternatives and negotiate our decisions.

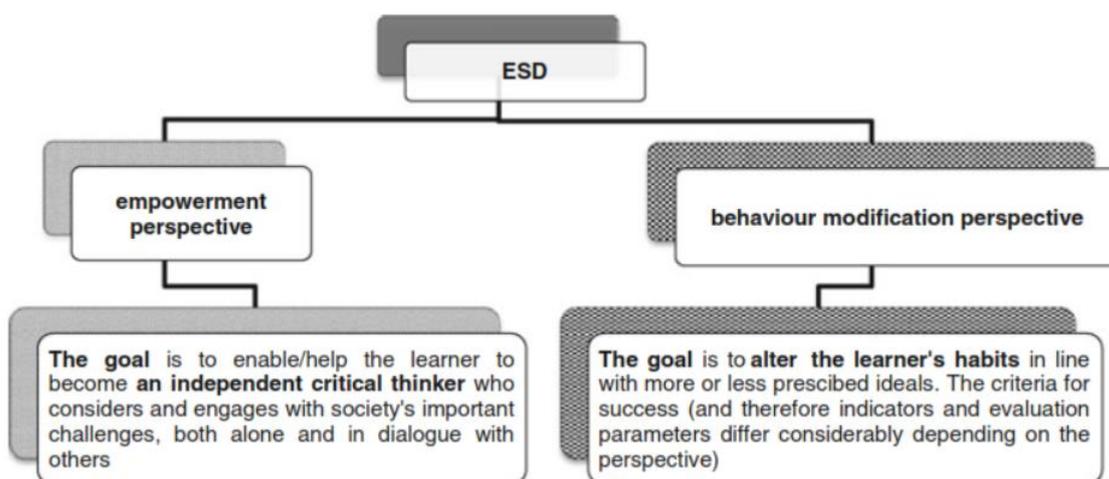


Figure 1. ESD with Empowerment and Behaviour Modification Perspectives

SINGAPORE POLYTECHNIC COMMON CORE CURRICULUM

The Common Core Curriculum (CCC) of Singapore Polytechnic aims to equip all SP graduates with foundational core skills that matter in a disruptive world.

Comprising 10 modules (Singapore Polytechnic, 2021), the CCC curriculum features skills that students would need to thrive in many industries that are facing or will face massive disruption. These skills include emerging digital skills like artificial intelligence (AI) and data fluency, and human skills like critical and digital communication skills. Among the 10 modules are also 3 modules that are constructed as hybrid modules – *Problem Solving with Creative*

and Computational Thinking, Persuasive Communication and Data Storytelling, and Sustainable Innovation Project.

More importantly, the 10 modules are set in the context of UN SDGs. This is key in the design of the CCC as the curriculum would allow students to understand the wicked problems framed in the UN SDGs. The specific skills taught in each CCC module would expand students understanding of and allow them to think critically about various UN SDGs seen locally and globally. Students then consolidate their learning in the CCC by coming together in multi-disciplinary teams to ideate solutions to UN SDG challenges in Singapore in the module, *Sustainable Innovation Project*.

The CCC modules are designed to be baseline skills that are transferable across industries. Hence, to ensure that students are able to use and apply these common core skills to the field of their study, the CCC team works closely with all domain diplomas to integrate CCC skills into their curriculum. . This is done via featuring UN SDGs that are critical to key industries of domain diplomas in CCC modules and coming together to “pair” assessments such that assessment completed in CCC modules are done in partial fulfilment of another assessment in their domain diploma.

USING CDIO CORE STANDARDS TO GUIDE DESIGN OF ESD

SP introduced a pilot run of this CCC-integrated curriculum with 2 diplomas in Semester 1, Academic Year 2021/2022 which began in mid-April 2022 for its new cohort of Year 1 students. At the time of this writing, students from the 2 diplomas – Diploma in Optometry (DOPT) and Diploma in Aerospace Electronics (DASE) – had completed one semester of study. When CCC is implemented fully across all diplomas in SP, most students will take CCC modules in year 1 and 2 of their study.

The 3 authors worked in various capacities along with a team of lecturers to bring the 2 pilot programs to fruition. The CCC team comprised of lecturers from the School of Life Skills and Communication (LSC) and the School of Mathematics and Science (MS). The second and third author co-leads the team in driving the CCC initiative. ; while the first author served as advisor on matters pertaining to CDIO and ESD, as he was at that time, also actively involved in reviewing the approach to ESD in the Diploma in Chemical Engineering (DCHE) where he is affiliated with academically. He was working closely with the DCHE team to prepare the diploma to come on-board in Academic Year 2022/2023 as the “second tranche” of programs to introduce CCC.

The first author reviewed and reflected on how he used the CDIO Framework to guide the curriculum redesign and distilled the key considerations on the approach that any diploma can take in the journey towards introducing CCC into the core domain curriculum and use the appropriate UN SGDs as learning context. The approach taken is that of a standard-by-standard explanation on how each standard can be interpreted through the lens of sustainable development. For the needed key competencies needed, references were taken from the CDIO Syllabus, and well as the CCC modules. The result is shown in Table 1.

Table 1. Guiding Principles for Curriculum Design for ESD using CDIO and CCC

Core Standard No.	Curriculum Design to include Sustainable Development
1. The Context	No change is needed for this standard. However, an emphasis can be added to highlight that the product, process, system or service should address one or more UN SDGs.
2. Learning Outcomes	Elaborate on the existing description: With reference to the CDIO Syllabus and the CCC, intended learning outcomes for key competencies for sustainable development – covered earlier in Cheah (2021) – are captured in module syllabus at course-level, and repeated in each integrated learning experiences at the task-level. The latter should be contextualized to the specific task and learning desired.
3. Integrated Curriculum	Enhance existing standard with the suggestion for achieving “dual-impact learning” approach via the 2 pathways of chemical process design and chemical product design (Cheah, 2021); with emphasis that sustainability principles can be used in both chemical plant operation and chemical product design using the same set of chemical engineering principles. Through thoughtful “pairing” with selected CCC modules, via both horizontal (reinforcement) and vertical (levelling up) integration to progressively develop knowledge, skills and attitudes required. “In-Module” integration can still take place for CCC modules that are designed to be standalone.
4. Introduction to Engineering	Supplement existing standard: Emphasize roles and responsibilities of professionals towards the discipline, as well as to society, with reference to the UN SDGs. Module such as “ <i>Introduction to Chemical Engineering</i> ” can be “unofficially paired” with “introductory” standalone CCC module “ <i>Thinking Critically about the UN SDGs</i> ”. This is also a good place to introduce specific UN SDGs as the focus areas of one’s profession.
5. Design-Implement Experiences	Include an added emphasis for project-based learning via a “project spine” themed after sustainable development, with projects from keystone to capstone (Cheah, 2014; Yang & Cheah, 2014) to support the product design track. However, the CCC module “ <i>Sustainable Innovation Project</i> ” will remain as standalone; so as to enable students from different courses to work together in a multi-disciplinary manner.
6. Engineering Learning Workspaces	No changes needed for this standard: students continue to use of learning workspaces in existing facilities. However, efforts such as energy-saving, water conservation, use of less chemicals, etc should be emphasized.
7. Integrated Learning Experiences	Include an added emphasis that these experiences should preferably address several UN SDGs within the same learning context, to reflect the interconnectedness of these 17 goals; and engage students is using a range of key competencies needed for sustainable development.
8. Active Learning	Emphasize greater use of collaborative learning with the help of technologies (such as Jamboard or Google Docs) to elicit different viewpoints from students in the context of appropriate UN SDGs to develop key competencies needed for sustainable development
9. Enhancement of Faculty Competence	The first author had developed 2 half-day workshops for help colleagues to first familiarize themselves with ESD and then to use the CDIO Framework when designing integrated learning experiences for their modules that are “paired” with the CCC modules:
10. Enhancement of Faculty Teaching Competence	

	The first author also conduct sharing sessions featuring a case study based on his work done in the Diploma in Chemical Engineering
11. Learning Assessment	Include suggestions to carry out joint assessment where feasible for core modules “paired” with CCC modules, at least for the key competencies; focus in particular on the transformative aspect of an integrated learning experience or a design-implement experience; ensuring the usual constructive alignment is applied.
12. Program Evaluation	No change to this standard. This shall follow existing process as per SP Academic Quality Management System, with the added lens of the CDIO Framework. As will be elaborated in the main text, one consideration is to make use of self-evaluation rubrics of the CDIO Optional Standard 1 Sustainable Development

Although the guidelines are developed based on integration with CCC, which is decided based on SP’s educational needs, it is believed that the approach is useful and applicable to members in the CDIO community who wish to introduce ESD into their respective programs.

OUTCOMES OF PILOT RUN: CHALLENGES AND LEARNING POINTS

The CCC team conducted an evaluation of the pilot run of the CCC in 2 diplomas – Diploma in Aerospace Electronics (DASE) and Diploma in Optometry (DOPT) with a total of 150 students. The evaluation of the pilot run was done at the end of Semester 1 of AY21/22, with a focus on the learning experience of students. The evaluation comprised a survey and two focus group discussions.

The questions designed for the survey and focus group discussions aimed to find out:

- (a) students’ knowledge of UN SDGs
- (b) views on the usefulness of the CCC skills taught to their field of study and life
- (c) perceptions about the workload in CCC modules

About 90% of the 150 students who were in the pilot run of the CCC participated in the survey and the team conducted two focus group discussions with 15 students. Some keys findings of the evaluation are as follows:

- Students gained useful knowledge (e.g. Un SDGs) and skills (e.g. digital communication skills)
- Students could also see the integration of the CCC into their field of study. Students saw skills taught in the CCC to be relevant to and could be applied to the industry of their field of study and even life at large.
- Students differed on their views on the workload in the CCC modules. Some felt that the workload was manageable while others wanted greater depth to the assignments.

Overall, students responded positively to the pilot run of the CCC. Even the Course Chairs of DASE and DOPT gave very positive response on how collaboration between the domain diplomas and the CCC gave students good baseline knowledge of UN SGDs and an integrated learning experience.

One key area of improvement that surfaced in the evaluation was the issue of communicating to students the requirements for assessments that were paired. Students received different instructions on these paired assessment. This issue had been resolved with discussions with the respective Course Chairs.

MOVING AHEAD

The learning points will no doubt be given due considerations when rolling out other CCC modules for Year 2, as well as for the next batch of diplomas. Plans are already in place for a next batch of diplomas, which besides DCHE as mentioned earlier from the School of Chemical and Life Sciences, will include another 10 diplomas from various other schools.

In the near future, the next natural step is to evaluate how well each diploma carried out the integration of sustainable development in its respective curriculum via the CCC. To this end, we can take reference from the work done in KTH Royal Institute of Technology, as reported by Rosen, et al (2021). These authors reported on the used the newly-introduced Optional CDIO Standard for Sustainable Development to carry out an institution-wide evaluation of a large number of programs at the bachelor and master levels, and concluded that, with some minor changes to the standard rubrics, the new standard is a useful tool for evaluating, promoting, and guiding integration of sustainable development, not only in programs with particularly high ambitions regarding sustainable development, but in basically any engineering program.

In SP, we can adopt a similar approach and adapt it for our own context. This can be on top of the usual sharing process via our Pedagogy Exchange platform; which is a monthly session organized by SP's Department of Educational Development. In addition, to more effectively learn from one another, we can also embark on some form of a peer-to-peer review process, in a manner similar to the ISO9001 Internal Audit, in that representative from say 2 schools undertook the review of the work done in another school. The other alternative is to engage a neutral third party, such as a member institution from the CDIO Community, in the form of some sort of a Peer-to-Peer Review, which is under consideration among CDIO Council Members.

Over the longer term, SP can consider actively promoting sustainability within its own campus, using the concept of "Living Labs". Verhoef & Bossert (2019) see Living Labs as new ways of innovation and are defined as user-centered, open innovation ecosystems based on a systematic user co-creation approach, integrating research and innovation processes in real life communities and settings. This may provide the context for our students contribute to sustainable development through the CCC module *Sustainable Innovation Project*, where they work in multi-disciplinary groups to apply the design thinking method and tools backed by research and qualitative data, to tackle local issues mapped to the UN SDGs. As part of the CDIO Integrated Curriculum, students will get to use what they have learnt in the CCC modules that come before this module to create sustainable and innovative prototype solutions for real-life issues faced by a local community in need. In the process, it is envisioned that students undergo a transformative process where they not only felt empowered to contribute to sustainable development, but more importantly, developed a better understanding of themselves.

To this end, we can draw on the recommendations reported on earlier by Finnveden, et al (2020); some of which had in fact used by the team designing the CCC. Specifically, the authors recommend that higher educational institutions do the following:

- (1) Decide on overall goals for integration of sustainable development and make sure that there are follow-up processes
- (2) Create an organization for the work on sustainable development and make sure it has resources to work
- (3) Let established definitions of sustainable development and Agenda 2030 be the starting point for higher educational institutions sustainability work
- (4) Avoid solutions where only a part of the higher educational institution is involved
- (5) Look for knowledge and engagement on sustainable development when recruiting leaders
- (6) Create structures and “institutions” for sustainable development that are sustainable and resilient
- (7) Support competence development of teachers and other staff
- (8) Focus not only on content but also on ways of teaching, creating transformative learning environments and pedagogic expressions
- (9) Create possibilities for interdisciplinary cooperation
- (10) Support student involvement and collaboration with companies and the public sector
- (11) Include sustainable development in Bachelor and Master theses
- (12) Support cooperation between different higher education institutions

These suggestions can be further deliberated upon when more diplomas come on-board and implemented CCC into their respective curriculum. As noted earlier, SP had adopted a phased-approach in this new endeavour, and the process will necessarily be an iterative ones. There will be rich learning experiences from all involved, and collectively such learning can serve to improve the overall implementation towards education for sustainable development in SP.

CONCLUSION

This paper shared a broad approach that can be used by any program seeking to integrate sustainable development into its curriculum using the CDIO Framework. The approach comprises a set of common core curriculum serving to provide the foundational digital and human skills that can be infused into a program’s domain core curriculum. The common core curriculum uses suitable UN SDGs contextualized to the key focus areas of each program, providing each program with its own unique integrated curriculum that allows students to use these digital and human skills not only in their respective domain areas, but also to contribute to sustainable development. This can be delivered through a series of integrated learning experiences, and a project-based learning module entitled *Sustainable Innovation Project*. A set of guidance questions based on the 12 Core CDIO Standards had been formulated to assist program owners to assist them in the curriculum redesign effort. Findings from the pilot run of this approach showed that students responded positive to this way of learning about sustainable development, and some ideas for future works are presented. Future papers may shares specific case studies of such an institutional-wide approach towards education for sustainable development.

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REFERENCES

- Barth, M. & Michelsen, G. (2013). Learning for Change: An Educational Contribution to Sustainability Science, *Sustainability Science*, Vol.8, pp.103-119
- Borge, R., Fernández, F.J., Muñoz-Guijosa, J.M., Moreno, A., Tanarro, C., Miñano, R. & Lumbreras, J. (2017). Integrating Sustainability as a Critical Skill in a CDIO “Product Development” Course, *Proceedings of the 13th International CDIO Conference, University of Calgary*, June 18-22; Calgary, Canada
- Cheah, S.M. (2021). Sustainable Development in Chemical Engineering Curriculum: Review and Moving Ahead, *Proceedings of the 17th International CDIO Conference*, hosted online by Chulalongkorn University & Rajamangala University of Technology Thanyaburi, June 21-23; Bangkok, Thailand
- Cheah, S.M. (2014). CDIO as Curriculum Model for Education for Sustainable Development, *Proceedings of the 10th International CDIO Conference*, June 15-19; Barcelona, Spain
- Chua, P.H. & Cheah, S.M. (2013). Education for Sustainable Development using Design Thinking and Appropriate Technology, *Proceedings of the 9th International CDIO Conference*, June 10-13; Cambridge, Massachusetts, USA
- Disterheft, A., Caeiro, S., Azeiteiro, U.M. & Filho, W.L. (2013). *Sustainability Science and Education for Sustainable Development in Universities: A Way for Transition*, in Caeiro, S. et al (eds). Sustainability Assessment Tools in Higher Education Institutions, Springer International Publishing, Switzerland
- Finnveden, G., Friman, E., Mogren, A., Palmer, H., Sund, P., Carstedt, G., Lundberg, S., Robertsson, B., Rodhe, H. & Svard, L. (2020). Evaluation of Integration of Sustainable Development in Higher Education in Sweden, *International Journal of Sustainability in Higher Education*, Vol.21, No.4, pp.685-698
- Hussman, P.M., Trandum, C. & Vigild, M.E. (2010). How to Include Sustainability in Engineering Education? The “Green Challenge” at DTU is One Way, *Proceedings of the 6th International CDIO Conference, École Polytechnique*, June 15-18; Montréal, Canada
- Læssøe, J., Schnack, K., Breiting, S., & Rolls, S. (2009). Climate Change and Sustainable Development: The Response from Education, International Alliance of Leading Education Institutes.
- Edström, K., Rosén, A., Hugo, R. & Campbell, D. (2020). Optional CDIO Standards: Sustainable Development, Simulation-based Mathematics, Engineering Entrepreneurship, Internationalisation & Mobility, *Proceedings of the 16th International CDIO Conference, hosted on-line by Chalmers University of Technology*, June 9-11; Gothenburg, Sweden
- Malmqvist, J., Edström, K. & Hugo, R. (2017). A Proposal for Introducing Optional CDIO Standards, *Proceedings of the 13th International CDIO Conference, University of Calgary*, June 18-22; Calgary, Canada
- Rosen, A., Hermansson, H., Finnveden, G. & Edstrom, K. (2021). Experiences from Applying the CDIO Standard for Sustainable Development in Institution-wide Program Evaluations, *Proceedings of the 17th International CDIO Conference*, hosted online by Chulalongkorn University & Rajamangala University of Technology Thanyaburi; June 21-23, Bangkok, Thailand
- Rosén, A., Edström, K., Grøm, A., Gumaelius, L., Munkebo Hussmann, P., Högfeldt, A-K., Karvinen, M., Keskinen, M., Knutson Wedel, M., Lundqvist, U., Lyng, R., Malmqvist, J., Nygaard, M., Vigild, M., & Fruergaard Astrup, T. (2019). Mapping the CDIO Syllabus to the UNESCO Key Competencies for Sustainability, *Proceedings of the 15th International CDIO Conference*, Aarhus University, June 25-27; Aarhus, Denmark:
- Singapore Polytechnic (2021). *Common Core Curriculum: What you'll learn* [online]. Available from: <https://www.sp.edu.sg/sp/education/common-core-curriculum/what-you'll-learn> [Accessed 13 Dec 2021].

Sterling, S. (2010). Learning for Resilience, or the Resilient Learner? Towards a Necessary Reconciliation in a Paradigm of Sustainable Education, *Environmental Education Research*, Vol.16, No.5, pp.511-528

UNESCO (2012). *Education for Sustainable Development Sourcebook*, United Nations Educational, Scientific and Cultural Organization

UNESCO (2017). *Education for Sustainable Development: Learning Objectives*, United Nations Educational, Scientific and Cultural Organization

Uruburu, A., Moreno-Romero, A., Carrasco-Gallego, R., Borge, R., Lumbreras, J. & Miñano, R. (2018). Integrating Sustainability in Academic CDIO Subjects: A Review after Three Years of Experience, *Proceedings of the 14th International CDIO Conference, Kanazawa Institute of Technology*, June 28 – July 2; Kanazawa Japan

Vare, P. & Scott, W. (2007). Learning for a Change: Exploring the Relationship between Education and Sustainable Development, *Journal of Education for Sustainable Development*, Vol. 1(2), pp.191-198

Verhoef, L. & Bossert, M. (2019). *The University Campus as a Living Lab for Sustainability*. Delft University of Technology, Hochschule für Technik Stuttgart

Waas, T., Hugé, J., Verbruggen, A., & Wright, T. (2011). Sustainable Development: A Bird's Eye View, *Sustainability*, Vol. 3, pp.1637-1661

Wals, A. E. J. (2014). Sustainability in Higher Education in the Context of the UN DESD: A Review of Learning and Institutionalization Processes, *Journal of Cleaner Production*, Vol. 62, pp.8-15

Yang, K. & Cheah, S.M. (2014). Chemical Product Design as Foundation for Education as Sustainable Development, *Proceedings of the 10th International CDIO Conference*, June 15-19; Barcelona, Spain

BIOGRAPHICAL INFORMATION

Sin-Moh Cheah is the Lead Teaching and Learning Specialist in the School of Chemical and Life Sciences, Singapore Polytechnic, as well as the Head of the school's Teaching & Learning Unit. He spearheads the adoption of CDIO in the Diploma in Chemical Engineering curriculum. His academic interests include curriculum revamp, academic coaching and mentoring, and using ICT in education.

Lee Yee Lim is the Director of School of Life Skills and Communication (LSC), Singapore Polytechnic. She co-leads the design and implementation of the Common Core Curriculum that is offered to all students of Singapore Polytechnic.

Yunn Chyi Chao is the Director of School of Mathematics and Science (MS), Singapore Polytechnic. She co-leads the design and implementation of the Common Core Curriculum with Director of LSC.

Corresponding author: ESD

Mr. Sin-Moh Cheah
School of Chemical & Life Sciences,
Singapore Polytechnic
500 Dover Road, Singapore 139651
smcheah@sp.edu.sg



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