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Research summary

Fostering computational thinking and design thinking in the IB Primary Years Programme, Middle Years Programme and Diploma Programme

James D Slotta, University of Toronto, Jie Chao, The Concord Consortium, Mike Tissenbaum, University of Illinois at Urbana-Champaign

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Background

Design thinking (DT) and computational thinking (CT) have been recognized by many as being critical 21st-century competencies needed for students' long-term educational and career success. DT is said to be at the heart of productive creativity and is identified as a key value in many industries. CT is seen as a basic understanding of how computers and technologies work. Considering the need for this type of competency development for the 21st century, this study included four aims: (1) to provide clarity around definitions of DT and CT for International Baccalaureate (IB) stakeholders; (2) to describe how DT and CT are currently represented within IB courses and programmes; (3) to discuss the challenges for teachers in implementing DT and CT in their current teaching and assessment practices; and (4) to provide guidance for future curriculum and implementation practices. The study also sought to identify some best practices for integrating DT and CT within the IB curriculum and assessments, and to articulate some implications for teacher practice and professional development.

Methodology

This study addressed four research questions.

1. What are the current definitions of CT and DT, including any research on their relation to learning progressions, assessments, curriculum integration approaches, and teachers' knowledge, practice and professional development?
2. How do IB courses and programmes currently incorporate CT and DT in their guides, assessments and teacher support materials (TSMs)?
3. How do the IB teachers understand DT and CT, and support their integration within their courses?
4. What are some key challenges confronted by IB teachers in terms of implementing CT and DT, and what are any considerations for supporting their future success?

The study included a literature review, curriculum audit and survey of teachers. The literature review provided a search of research papers published since 2006. The curriculum audit was done on selected courses to reveal how DT and CT are integrated within and across the programmes. The survey of teachers provided insight into how IB teachers understand these constructs, how they accommodate them within their curricular designs, and any challenges they perceive regarding the inclusion of DT and CT.

Findings

Literature review

The literature review addressed four specific aspects concerned with DT and CT.

Definitions of DT and CT

Most definitions of DT and CT emphasize the importance of open-ended problems or projects that students must solve through collaboration, creativity and design. DT and CT are also mutually reinforcing. Because DT and CT have many common underlying dimensions, activities and resources, each competency often includes some degree of the other.

Based on the literature review findings, the following working definitions were articulated.

- Design thinking: A form of thinking in which learners collaboratively and iteratively develop creative solutions for open-ended, unstructured real-world problems.
- Computational thinking: A particular form of problem-solving and reasoning in which the learner addresses open-ended problems to formulate the problem in such a way that its solutions can be represented as algorithms that can be worked through either by computers or humans.

Curriculum integration and learning progressions

The most effective curriculum design strategies are those that address CT and DT explicitly and employ project-based or design-centred approaches. Activities that integrate DT and CT are frequently reported as being multidisciplinary in nature (for example, within science, technology, engineering and mathematics (STEM) projects) and even entail collaborations among teachers from different courses.

DT and CT are described as competencies (ways of knowing and learning) that students acquire and apply during engagement with the curriculum. Many scholars describe DT and CT as competencies that will serve students in learning across disciplines and throughout their lives. It is important that teachers see DT and CT not as topics to "cover" but rather as a means of covering topics.

There is a lack of comprehensive, measurable assessments for DT and CT. This clearly reflects the relative recency of these terms and their lack of widespread adoption as core elements in curriculum frameworks. It also reflects the challenge of assessing open-ended problems or substantive multidisciplinary projects.

Learning contexts and environments

DT and CT can be applied flexibly to support learning that spans formal and informal contexts, and across subject domains. Much of the research concerning DT and CT has been conducted within informal settings such as museums or after-school programmes. However, this research typically recognizes its relevance to formal contexts within K–16 education.

A wide range of platforms can support students in engaging in CT, while far fewer are explicitly dedicated to DT.

Platforms that support engagement with CT

- Spreadsheets
- Block-based programming environments such as Scratch or the Massachusetts Institute of Technology's App Inventor (Morelli et al 2011)
- Hybrid programming environments such as Game Maker (Jenson and Droumeva 2016)
- Non-computer-based activities can also effectively engage students in CT, allowing the modelling of problems and formulation of solutions before jumping into computation (Lee et al 2014)

Platforms that support engagement for both CT and DT

- Robotics construction kits are popular (Sullivan and Heffernan 2016)
- Microworlds such as Lattice Land (Pei et al 2018) or Paper Circuit (Lee and Recker 2018) that allow learners to explore disciplinary ideas through computational manipulations

Teaching with DT and CT

Teachers' pre-existing ideas about DT and CT may inhibit their integration of related new forms of practice and classroom discourse. Students are largely in charge of their own learning activities, constrained by curriculum guidelines, and are often blending school, home and disciplinary contexts. The teacher will be engaged most often with individuals and small groups, periodically calling the class together for short periods of instruction or discussion. This places teachers in a role of mentorship, and results in discourse patterns such as "accountable talk" (Resnick et al 2018) or "responsive teaching" (Robertson et al 2015).

Although there have been few research studies that address teachers' learning of DT and CT, some published studies suggest that effective teacher professional development should engage teachers in learning through DT and CT activities, so that they can experience first-hand how DT and CT engage thinking and reasoning within their domain.

Curriculum audit

This section reports findings related to the integration of DT and CT within the Primary Years Programme (PYP), Middle Years Programme (MYP) and Diploma Programme (DP). Three main findings are articulated below.

1. Current IB programmes emphasize real-world problems and many courses include a focus on open-ended problems, creativity and design. All three IB programmes (PYP, MYP and DP) make a concerted effort to connect student learning to real-world problems, creative thinking, and multidisciplinary approaches.

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2. Some dimensions of DT and CT—such as collaboration and iterative improvement—are recognized explicitly as values within the IB, especially in the MYP. However, they are not typically addressed with any explicit guidance, assessments or TSMs.
3. Many dimensions of DT and CT were found within the course materials, but these were likely present because of an overarching commitment to inquiry and project-based learning, which share some of the same dimensions (such as creativity or real-world problems). While creativity and problem-solving were regularly highlighted, other dimensions of DT (such as iterative testing and revision) and CT (such as algorithms and problem decomposition) were much less prominent, presumably because they are more specific to design and computation.

Survey of teachers

The survey examined teachers' self-reported understandings of DT and CT, their approaches to integrating these competencies, and the challenges they perceived in doing so.

Teachers' understandings of DT and CT

1. Teachers from all three programmes reported a high level of familiarity with, and understanding of, DT and CT and how it can fit within their courses. Teachers broadly reported that they are aware of and understand DT and CT as critical 21st-century competencies.
2. Project-based work is commonly cited as a strategy where students must engage in creative problem-solving. There is a common recognition of the value of open-ended projects in which students must creatively apply the ideas and topics from the course.
3. Some teachers expressed limited understandings or lack of confidence in how to integrate DT and CT. Many teachers across the programmes expressed a need for additional guidance, case studies and other forms of teacher professional development or TSMs designed to help them understand and integrate these competencies more deeply.

These are self-reported understandings, so it is possible or even probable that some respondents believe they have stronger understandings than they actually do. Nonetheless, teachers' reported understandings should be seen as a positive outcome and certainly indicate a positive attitude of teachers regarding CT and DT. For further details about "Teachers' understandings of CT and DT" see Section 3 of the full report.

Approaches to integrating DT and CT

There were many common teacher approaches to integrating DT and CT that occurred across all three programmes, and some that were specific to a particular programme. Table 1 presents each programme in terms of the key strategies used by teachers.

IB programme	Overview	Key strategies
DP	DP teachers shared a range of interesting ideas and approaches. Instructors offered fewer specific illustrations and activities for CT than they did for DT, with many appealing to the more general computational nature of problem-solving.	• The use of open-ended and student-centred problems • Inclusion of technology-based activities • Use of data management and computation in projects and problem-solving • Scientific method and problem-solving • Emphasizing collaboration • Multidisciplinary partnerships with DP Design technology
MYP	MYP teachers recounted a range of interesting ideas and approaches that were similar to those expressed by DP teachers.	• The use of authentic, open-ended problems • The use of iterative cycles of revision • The use of collaborative projects • Supporting creativity • Connecting design and computation • Integrating programmable hardware technologies • The use of programming environments • Working with data
PYP	PYP teachers showed a remarkable sensitivity to the importance of DT and CT, and strategic insight about how to target those competencies.	Strategies for younger students (age 3–6 years) • Play and creativity • Open-ended problems • Collaboration or group work • Finding patterns • Breaking problems into smaller parts • The use of puzzles and problems • Adding technology Strategies for older students (age 7–12 years) included many of those same strategies, as well as the following. • Computer games • Use of concept maps and flow charts • Robotics, and computer programming • Integration of topics across disciplines • Student-selected problems

Table 1. Approaches to integrating DT and CT by IB programme

Challenges identified by IB teachers

1. Many DP teachers feel there is too much required content and not enough curriculum time for the introduction of project-based approaches and/or open-ended problems. In the MYP, fewer teachers cited the heavy content requirements. However, there were some who argued that they needed more time for projects (for example, in mathematics and science). This suggests the need for a programme-wide emphasis on problem-solving, creativity and data-driven reasoning. In the PYP, some teachers expressed the need for more curricular time and age-appropriate assistance with integrating DT and CT, indicating that teachers

sometimes perceive a constraint or limitation imposed by their school's inquiry plans.

2. Teachers expressed the need for more guidance in designing and enacting activities that use DT and CT, as well as the need for appropriate evaluations. Many DP teachers cited the lack of strong examples of "how to do this", and the need for professional development. MYP teachers felt that, while there is a stated value of project-based learning and open-ended problems, there is a lack of guidance about what those look like for specific courses. PYP teachers often cited the need for more support in adapting their inquiries to include DT and CT integration.
3. Some teachers, especially in the PYP, feel that their students are not ready for such forms of curriculum. This is either because of perceived behavioural issues or because the teachers believed these forms of learning are developmentally inappropriate.

Considerations for IB programmes

In response to the challenges identified in the previous section, several considerations were articulated, both at a general (cross-programme) and specific (within-programme) level (see table 2).

IB programme	Considerations
Across all programmes	• Improve the guides and TSMs, making explicit reference to DT and CT as a basis for powerful teaching and learning and as important 21st-century competencies. • Make the assessment of DT and CT explicit, so that they will be taken seriously (by students and teachers). • Adopt programme-wide emphasis on interdisciplinary projects and revisit breadth of content. • Support the exchange of programmes of inquiry and lesson plans among IB teachers. • Create programme-level plans for teacher professional development that can support schools in helping teachers become more knowledgeable and reflective in their practice. • Consider design and computation within the landscape of professional practice in the relevant disciplines (such as mathematics, chemistry, engineering).
DP	• Engage in some re-design of curriculum expectations, reducing the amount of core content and adding an emphasis on multidisciplinary projects. • Strengthening interdisciplinary connections between computer science, mathematics and sciences could be one strategy (for example, creating a multidisciplinary project requirement). • Considering career identity development is vital, and the DP could make a concerted effort to work with the IB Career-related Programme (CP) to strengthen links with and from the CP core, such as: (1) incorporating aspects of its reflective projects with a career focus; (2) including personal and professional skills links in courses groups; and (3) focusing on specific skills learning. • Find a way to infuse more space in the curriculum for project-based learning approaches, such as in the internal assessment models of DP courses.
MYP	• Explicit integration of DT and CT into MYP projects' key and related concepts and the programmes of inquiry as reflected in the unit planning process, referring to the dimensions of our working definitions.

	• Support the exchange of lesson and assessment plans among MYP teachers across the programme, which could also provide a powerful source of content and help to disseminate effective designs.
PYP	• Greater emphasis could be placed on students' learning progressions and on how these can be supported in the programmes of inquiry: Where do students start, in relation to problem-centred, creative and collaborative approaches, and how can we support their development? • Specific guidance could be offered around DT and CT to help teachers understand how these competencies will be impacted by a variety of approaches. • More effort could also address the progression of DT and CT throughout the programme, including a clear narrative about how design and computation are things that PYP students learn about and how these will be critical for success in the MYP and beyond.

Table 2. Considerations for IB programmes

Summary

DT and CT are seen as critical 21st-century competencies that will serve students in learning across disciplines and throughout their lives. Definitions of DT and CT emphasize the importance of open-ended problems or projects that students must solve through collaboration, creativity and design. The most effective curriculum design strategies are those that address CT and DT explicitly and employ project-based or design-centred approaches. IB teachers from all programmes report a high level of familiarity with, and understanding of, DT and CT and how it can fit within their courses. However, many teachers across the programmes expressed a need for additional guidance, case studies and other forms of teacher professional development, as well as the need for assessments. Considerations for the IB programmes include improving guides and TSMs, making explicit reference to DT and CT as a basis for powerful teaching and learning and as important 21st-century competencies.

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