Teaching and Learning Design Thinking (DT): How Do Educators See DT Fitting into the Classroom?

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Abstract

As a problem-solving approach, design thinking (DT) emphasizes iterative, user-focused designing. While DT is being readily adopted into education, little is known about how educators integrate DT across curricula. To address this question, we collaborated with a tech-ed industry partner and a focus group of experienced educators to assess curriculum content developed using a DT framework. Results showed that educators expressed positive impressions of the DT framework and lesson plans, but also identified potential challenges to integrating DT into classrooms (e.g., assessing skills and attitudes related to DT). Findings suggest that DT-based learning aligns with a shift from project-based instruction to experiential learning aimed at achieving global competencies.

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Keywords: design thinking, education, teaching, assessment, creativity, global competencies

Résumé

En tant qu'approche par résolution de problèmes, la pensée conceptuelle (DT) met l'accent sur la conception itérative et axée sur l'utilisateur. Bien que la DT soit adoptée volontiers en éducation, on sait peu de choses sur la façon dont les éducateurs intègrent la DT dans les programmes. Pour répondre à cette question, nous avons collaboré avec un partenaire industriel des technologies de l'éducation et un groupe de discussion composé d'éducateurs expérimentés afin d'évaluer le contenu des programmes d'études élaborés à l'aide d'un cadre DT. Les résultats démontrent que les éducateurs perçoivent positivement le cadre et les plans de cours de la DT, mais ils identifient également des défis potentiels à l'intégration de la DT dans les salles de classe (par exemple, l'évaluation des compétences et des attitudes liées à la DT). Les résultats indiquent que l'apprentissage basé sur la DT s'harmonise avec le passage d'un enseignement par projet à un apprentissage expérientiel visant à acquérir des compétences globales.

Mots-clés : pensée conceptuelle, éducation, enseignement, évaluation, créativité, compétences globales

Introduction

Recently, education scholars and practitioners have called for emphasis on developing skills such as critical thinking, collaboration, and problem solving needed for success in the 21st century (Organisation for Economic Co-operation and Development [OECD], 2003, 2018; Battelle for Kids, 2019). To prepare students for success in the globalized digital world, it is essential that they learn and practise these new skills early in their education. One way to cultivate this skillset is to combine knowledge from computer science (CS), such as computational thinking, coding, and digital technologies, with existing core curriculum content (Hennessey et al., 2017; Wing, 2006).

Given the relevance of technology and innovation to advancing society in general, education has adopted computational thinking (CT), or thinking like a computer scientist, to solve problems (Wing, 2006). While CT is being widely integrated into classrooms, research and practice are working simultaneously to reach consensus on where CT may already exist across disciplines (Hennessey et al., 2017), and a reliable way to assess the successful teaching of CT (Mueller et al., 2017). At the same time, education and industry have also adopted another approach to problem solving called design thinking (DT), an iteration-focused design approach popularized by the Hasso Plattner Institute at Stanford University at the Stanford d.school (Hasso Plattner Institute, 2007; Plattner et al., 2009). This design process can be considered complementary to CT, given the focus on "failing forward" as students revise repeatedly to achieve the desired outcome. Innovative solutions to modern problems are ever-emerging throughout education systems, from elementary to post-secondary, as a result of this process (Buitrago Flórez et al., 2017; Crichton & Childs, 2016; Hawthorne et al., 2014). While this approach has gained traction through accessible institutions like the Stanford d.school, DT has been long-practised by systems-theorists and designers beginning in the early twentieth century (Buchanan, 2019) and across fields such as industrial design, commercial marketing, and architecture (Cross, 2011).

As new and different types of thinking are integrated into teaching, it will be important to explore how one key group of stakeholders, the educators, think about and implement DT into education and across disciplines. Moreover, as DT becomes more frequently applied in educational settings, it will be essential to assess how DT affects educators' experiences and practices. To that end, we conducted a focus group with educators, in collaboration with an industry partner who had developed design-based lesson plans to accompany their 3D printers, with two purposes in mind: (1) to gain insight into educators' perceptions of curriculum content designed with a DT framework, and (2) to investigate how educators perceive DT "fitting" into their classrooms. The primary purpose of this study was to provide an introductory examination of how DT might be integrated into teaching and learning and to initiate the discussion on how DT fits into classroom practice.

Design Thinking (DT) Defined

According to the commonly cited Stanford d.school model (e.g., Melles et al., 2012; Plattner et al., 2009), the DT process includes five stages: empathize, define, ideate, prototype, and test. This process underlines how designers should first empathize with the user of the final product or service to ensure that the design process is fuelled by human needs. By defining the problem, imagining solutions, and testing them, designers can ensure they meet the users' needs rather than addressing another extraneous purpose. Importantly, the cornerstone of the DT process is its iterative nature, such that all stages can be repeated or returned to at any time until the design is fully optimized. This characteristic flexibility promotes interaction among different disciplines like science, business, and engineering, and creates a learning environment that facilitates fast-paced iteration and prototyping (Plattner et al., 2009).

In addition to the five fundamental stages of DT, there are four guiding DT principles delineated in Plattner et al. (2009). First, it should be recognized that all design is governed by the need to satisfy the user, also known as a human-centric approach to design. Second, designers should maintain some sense of ambiguity when designing so that alternative solutions and perspectives remain possible. Third, all designs should be subject to continued iteration so that products or services reliably meet people's needs. Fourth, those using a DT approach should strive for ideas and prototypes that are tangible. As these principles suggest, DT aims to meet the practical needs of human beings while constantly monitoring for adaptations and modifications.

While DT is historically rooted in industrial design and engineering, it has more recently been of interest to those in a wide range of professions, including design industries and emerging technologies (Adams & Nash, 2016; Brown, 2008; Martin, 2009;

Rotherham & Willingham, 2009). In industry, definitions of the DT process support those put forth by the Stanford d.school and Stanford scholars. Demonstrating continuity across education and industry contexts, Schmiedgen et al. (2016) asked participants from different organizations to define DT. Participants' responses included several criteria in line with the d.school's DT process. For example, participants described DT as (1) an iterative process; (2) a "special" way of understanding and creatively solving problems; (3) an empathetic process; (4) a collaborative tool; (5) a mindset; (6) a toolbox for user research and group creativity; (7) a way to prototype; and (8) a culture. Notably, in addition to identifying these defining criteria, the majority (71%) of participants also reported that DT had a positive impact in their workplace. These are intriguing findings given that DT is seldom measured. Only 24% of organizations assessed by Schmiedgen et al. in their study (2016) indicated measuring the effects of DT at all. Given the scarcity of research assessing DT, one purpose of the present work was to gain insight about a potential framework for assessing DT in education.

Assessing Creativity or Design Thinking?

One potential challenge associated with implementing DT in an educational context is assessment. Given that DT shares some crossover with general creativity (e.g., generating solutions, reiterating), it is not surprising that many DT assessments are based on tests of creativity. As in Hawthorne et al. (2014), creativity refers to "a state of being and adaptation of personal skill sets that enables an individual to synthesize novel connections and express meaningful outcomes" (p. 113). This definition overlaps with the way in which DT emphasizes continuous iteration throughout the design process. But how does one assess creativity? One common group of creativity assessments is known as *convergent* thinking tests, which evaluate the ability to connect multiple different ideas to develop a shared solution. For example, the Remote Association Test (Mednick, 1962) presents participants with three words (e.g., cottage, blue, and mouse) and they must identify what these words have in common (i.e., all are related to cheese).

Creativity can also be assessed by measuring *divergent* thinking, which is the ability to generate many solutions to a single problem. For example, the Torrance Test of Creative Thinking (Torrance, 1990) assesses creativity as an open-ended process using words or figures. In this test, participants are presented with a series of incomplete words or figures and asked to complete them in as many ways as possible. Similarly, Wallach and Kogan's Tests of Creative Capacity (1965) provides participants with a single word (e.g., wheels) and they must identify as many items that contain this component as possible. Given the overlap between DT and creativity in general, it is possible that the core activities involved in both will also cross over. For example, the ideation phase of DT could be considered parallel to the brainstorming process inherent in constructing a written essay. Indeed, a recent content analysis of computational thinking identified computational practices and perspectives across all disciplines, not just science and math (Hennessey et al., 2017).

One of the most widely used assessments of creativity is the Alternative Uses Test (Mendelsohn, 1976), in which participants are asked to generate as many uses for a single object as possible (e.g., a pen). In the context of the DT process, perhaps a similar approach could challenge students to design and create products that serve multiple functions for different populations. However, most relevant to DT is the Design Thinking Creativity Test (Hawthorne et al., 2014), which aims to capture the process and outcomes of the DT process. In addition to some of the more objective measurements of creativity, people can also assess their own creative thinking abilities and attitudes. For example, the Creative Attitude Survey (Schaefer & Bridges, 1970), the Creative Achievement Questionnaire (Carson et al., 2005), and the Creative Confidence Scale (Royalty et al., 2014) all include self-assessments of creative abilities. However, like all self-report measures, this approach to assessment has its own set of challenges.

As discussed in Hawthorne et al. (2014), approaches to assessing DT vary, from the use of student portfolios to standardized creativity measures. One benefit of individual case-based DT assessment is that educators can gauge the extent to which growth has occurred from the start to the end of the learning process. Indeed, one major focus of DT is the iterative nature of designing and improving designs. Yet because DT is an approach to problem solving, rather than a set of observable behaviours, as a construct, it remains challenging for educators to assess.

DT in Educational Contexts

DT's characteristic focus on collaboration and iteration is relevant to learning theories within education, developmental psychology, and social psychology. Vygotsky's (1976) social learning theory states that interacting with others is essential to learning, and experiential learning theory (Kolb, 1984) describes learning as the process through which knowledge results from gaining experience. Furthermore, the iterative nature of DT lends itself to a parallel with Dweck's (2006) research on implicit theories of the self, which suggest that people can possess fixed (i.e., I am who I am, and I cannot change much) or growth (i.e., I can change, learn, and grow) mindsets. Notably, cultivating a growth mindset among students has been associated with positive outcomes, such as higher achievement and greater persistence on challenging tasks (Yeager & Dweck, 2012). It is therefore possible that a DT mindset that emphasizes iteration will result in similar positive outcomes for students, such as persisting through different prototypes when altering designs.

In education, DT skills can be learned through pedagogical approaches that involve problem-based learning, project-based learning, or inquiry-based classroom activities (Dym et al., 2005). These approaches have been closely connected to the Makerspace movement in elementary schools (Crichton & Childs, 2016). Studies conducted in K–12 education have demonstrated the role of design-based learning in the improvement of students' skills across the curriculum in a variety of contexts, including problem solving (Anderson & Shattuck, 2012), mathematics (Goldman et al., 1998), anatomical systems (Hmelo et al., 2000), geographic systems (Carroll et al., 2010), interaction design (Dukes & Koch, 2012), and informal learning activities like developing art education tools (Roussou et al., 2007). In a variety of contexts, DT helps to foster innovation development through creative thinking and problem solving. It involves collaborative and human-centred activities that assist in solving complex problems and adjusting to unexpected changes (Razzouk & Shute, 2012). While definitions of DT may vary across disciplines, those definitions are all linked by the human-centred process that stems from empathizing with other people to meet real needs (Brown & Wyatt, 2010).

Research on DT in education has primarily examined the experiences of students. For example, Goldman et al. (2014) assessed how two student teams (independent of instructors) learned the DT process. Students' interviews indicated that the groups moved somewhat fluidly across DT stages; however, the iterative process also elicited some interpersonal conflict among team members. The authors noted that to manage such conflict arising from ambiguity, instructors should provide consistent support throughout all DT stages, as a sense of security could spark innovation. In addition to increasing innovation more generally, in schools DT has been identified as a way to promote experimentation, problem solving, and to turn feedback into solutions (Razzouk & Shute, 2012). More direct benefits to students are also observable; those who apply DT principles (versus those who do not) are more efficient and persistent problem solvers (Anderson & Shattuck, 2012). Much of the previous research on DT in teaching and learning has focused on the potential benefits for students (Chamberlain & Mendoza, 2017), whereas far less work has examined the experiences of teachers as they adopt DT into practice (Retna, 2016).

Some previous research has examined students' and educators' experiences with DT in the classroom. One study assessed how students and instructors responded to implementation of a design curriculum in a middle school geography classroom (Carroll et al., 2010). Over 12 hours of in-class time, students completed various activities related to the different stages of the DT process, including empathizing and prototyping. As students completed activities, the researchers recorded students' progress and educators' impressions. Three major themes emerged across student and educator data: (1) the DT process was characterized by exploration; (2) the DT process elicits positive mood and collaboration; and (3) the DT process can be applied to curriculum content across disciplines. Educators' responses also indicated that one of the greatest strengths of DT is that it gave students the opportunity to express themselves at each stage of the process. In all, this study highlights the critical role of educators in successfully integrating DT into the classroom and connecting DT principles to curriculum content.

In another relevant study, 17 DT experts (e.g., d.school teaching faculty from the US and Germany) were interviewed about what they hoped to achieve by implementing DT in their classrooms (Rauth et al., 2010). Overall, educators concurred that DT was a toolbox from which they could draw different skills and subjects to solve problems. They also reported that one goal of teaching with DT was to influence students' behaviour, such that learners would move away from a more traditional, project-based mindset to a more flexible, creative mindset that promotes iteration. Notably, educators reported combining knowledge from their previous professional backgrounds (i.e., as teachers, as administrators, in business) with DT to supplement the learning process. Such integration of previous knowledge with DT could support the transition into using DT in practice and make applying DT seem feasible in real-life situations and relevant across different subjects.

Arguably, there are several advantages to integrating DT into classrooms. For example, DT may present opportunities to explore novel learning and teaching environments, develop contextually-based theories of learning and teaching, advance design knowledge, and increase students' capacity for innovation (Design-Based Research Collective, 2003). Thus, there is great potential for integrating DT into learning and to support better understanding of educators' experiences with DT in the classroom. Despite the immense value in exploring educators' experiences working with DT, little previous research has assessed these experiences. The present study, therefore, was designed to be a first step toward advancing and merging knowledge from education research and design research to address two main research questions: How do educators understand the DT process? How do educators see DT fitting into their classrooms?

Methods

To answer these questions, we collaborated with an industry partner in educational technology. We chose this partner because they had familiarity with DT and were experienced in developing and implementing technology-based classroom activities involving 3D printing and robotics. While technology does not have to be utilized in DT activities, elements of technology are often the tools through which DT takes shape. In partnership with this technology company, we adapted the Stanford d.school process for implementation in a broader education context. Specifically, each stage in the d.school process was adjusted for clearer use among younger students. For example, where the d.school process begins with the need to "empathize" with the user, the revised USERS framework begins with the need to "understand" the perspective of the user. In all, the final revised stages delineated a DT process in which students will *understand* the users' needs, *specify* the challenge being addressed, *estimate* different solutions, *represent* these solutions in different ways, and *support* final designs (USERS).

Participants and Procedure

Prior to collecting data, we received clearance from the university's ethics review board. Following ethics approval, we recruited a focus group of educators (n = 8; 50% female, 50% male, $M_{yearsexperience}$ = 13.25, SD = 4.05) through targeted Twitter messages and email invitations to those in an existing network of educators experienced in integrating technology in the classroom. Participants completed an online intake survey to gauge attitudes toward technology in the classroom and knowledge of DT. Following the intake survey, educators met in person to participate in a focus group where they reviewed, and provided feedback on, curriculum content developed using a DT framework.

Online Intake Survey

Approximately two weeks before the focus group, educators were sent a secure link to an online intake survey. The survey asked both quantitative and qualitative questions about years of work experience, familiarity with and usage of technology in personal and professional contexts, understanding of DT, and perceptions of how DT might "fit" into the classroom. Forced choice items were rated on scales ranging from 1 (*Not at all*) to 5 (*Extremely familiar*) and 1 (*Not at all*) to 5 (*Very frequently*). The intention of collecting survey data was not to conduct inferential statistical tests, but rather to gauge workshop participants' experiences with technology in education.

Focus Group

Educators attended a two-and-a-half-hour focus group session hosted by the two primary researchers and two industry partner representatives. After a brief introduction to DT by the researchers, educators reviewed the USERS DT framework and two detailed lesson plans. Lesson plans had been developed and then programmed and displayed on an online teaching platform called Teachable[1] in collaboration with the industry partner. Using their personal electronic devices (i.e., tablets, laptops) educators were asked to view the plans individually and then provide feedback in relation to the lesson plan content, framework, and interface (e.g., how material was presented on Teachable). Following this review, the group discussed the curriculum content, providing commentary on how DT could be integrated into teaching and learning. Educators spent an average of 30 minutes reviewing each lesson plan, after which time they engaged in a group discussion moderated by the researchers.

Lesson plans. A set of lesson plans was developed by the researchers in conjunction with the educational technology industry partner. Content was meant to draw

1 Teachable is an online platform on which educators can create and access online courses, https://teachable.com/

connections across the social sciences as well as science and technology (e.g., sustainability, the atmosphere on another planet) and often involved a 3D printing activity. Lesson plans were designed to communicate course-related content and to present opportunities to cultivate global competencies such as collaboration and critical thinking (OECD, 2003 2018; Battelle for Kids, 2019).

Two lessons were selected for review in the study. The first lesson, titled "Mission to Mars," outlined multiple classroom sessions in which students are assigned roles and tasked with designing 3D-printed solutions for life on Mars. The second lesson, titled "One with Nature," also outlined multiple classroom sessions in which students collaborated to design a 3D-printed model of sustainable and eco-friendly building structures.

Results

The quantitative items on the intake survey served as a validity check that the sample of participants was at least somewhat familiar with working with technology. As expected, the survey revealed that educators were most familiar with assembling structural components like IKEA furniture, moderately familiar with installing electronics components and using coding languages, and least familiar with assembling and repairing electronics. In general, educators indicated using smartphones and laptops most often in their personal and professional lives, and gaming and robotics least often. Descriptive statistics for the sample of experts are displayed in Table 1.

Table 1. Descriptive statistics for quantitative intake survey items (*n* = 8)

Survey Items	Mean	SD
Familiarity with technology		
1. Assembling structural components such as IKEA furniture.	4.25	.71
2. Installing electronics components such as computers, stereo equipment, and/or televisions.	3.88	1.25
3. Using any type of coding language.	3.25	.46
4. Assembling or repairing electronics components such as computers or other electronic appliances.	2.50	.93
Technology use in personal life		
1. Smartphone	5.00	.00

Survey Items	Mean	SD
2. Laptop computer	4.63	.74
3. Tablet	3.63	1.41
4. Chromebooks	3.38	1.19
5. Desktop computer	2.75	1.49
6. Robotics	2.63	.92
7. Gaming	1.75	.71
Technology use in professional life		
1. Smartphone	4.88	.35
2. Laptop computer	4.50	.76
3. Chromebooks	4.38	.92
4. Tablet	4.00	1.07
5. Desktop computer	3.75	1.39
6. Robotics	3.25	.89
7. Gaming	2.13	1.13

Notes. Scales ranged from 1 (*Not at all familiar*) to 5 (*Extremely familiar*) and 1 (*Not at all*) to 5 (*Very frequently*).

Qualitative Intake Survey Item

Responses to four open-ended questions were reviewed to extract common themes that described the participants' understanding of DT and its integration in teaching.

1. What is your understanding of DT? All but one educator described DT as a process involving prototyping and iterative improvement. For example, one educator explained: "It involves identifying and articulating a problem, then iteratively developing solutions and feeding that process forward into subsequent problems." Another stated:

> Design thinking is an approach to problem solving that centres around the user—in such a way it involves developing empathy as a means to better identify and understand problems in order to develop solutions that meet the needs of the user. Creativity and critical thinking are key aspects in which learners ask questions, discover relevant information and develop prototypes. Design thinking is iterative in nature.

Overall, responses indicated that educators were somewhat familiar with and knowledgeable about the concept of DT, consistent with past research showing that even pre-service teachers are familiar with the basic tenets of DT (Willard-Holt et al., 2018).

2. Integrating DT into curricula. Educators mostly described using problem-solving projects, such as a 3D printing project, to integrate DT into their classrooms. One educator commented that DT is a tool that enhances learning while emphasizing the student-driven approach to assessment: "I use it as a tool to bring alive student learning… adding accountability to their work." Another educator commented on the role of integrating DT into the classroom to promote greater connection between curriculum content and bigger concepts, saying they enjoyed "integrating real-world problems into the classroom—using students' knowledge and interests to help [them] develop new skills that target big ideas in our curriculum." Educators commented on the ease with which DT could be paired with curriculum content. In general, educators believed that DT would fit well into teaching the scientific process and problem-based inquiry learning. Educators in a consultant role stated that they could see themselves providing support to educators implementing DT.

3. Resources needed to integrate DT into the classroom. Educators indicated two main resources that would facilitate integrating DT into their classrooms. First, many stated that collaboration and discussion with colleagues would be beneficial to generate ideas, including how to maximize activities during class time. Second, educators indicated that appropriate technological support would be advantageous to integrating DT into teaching.

4. Assessing DT in the classroom. Educators indicated that students should take an active role in assessing DT in the classroom. Some educators reported that tools such as student reflections, learning logs, and templates would be ideal student-driven approaches to assessing DT. One educator elaborated:

> Design thinking involves a great deal of research and problem solving. Finding curricular connections is not difficult. Once you experience learning in this way, you truly understand student-driven learning. The documentation of the learning journey is the assessment.

Given that DT emphasizes the users' needs in guiding the design process, it is not surprising that educators identified student-driven approaches as optimal ways to assess DT in the classroom.

Focus Group Themes

Educators were asked to view the plans individually and then provide feedback in relation to the lesson plan content, framework, and interface (e.g., how material was presented on Teachable). The feedback regarding the interface was not a central focus of the research, however, educators were keen to integrate perceptions of the interface during the discussion of the content. Opinions on the interface were intended to provide practical feedback for the industry partner. Therefore, the following results focus on responses related to the curriculum content and DT framework.

Throughout the focus group session, educators provided written and verbal feedback that was audio-recorded by researchers with the consent of participants. The group was structured in a roundtable format, so that each educator had the opportunity to share verbal feedback individually before engaging in a group discussion. Once completed, the focus group audio recording was transcribed and analyzed using analytic induction (Goetz & LeCompte, 1984), open coding (Strauss, 1987) and constant comparison (Glaser & Strauss, 1967). In this process, two trained researchers reviewed transcripts from the focus group and categorized responses according to common themes that emerged from the data. Any discrepancies in thematic analyses were resolved by discussion and consensus.

Perceptions of the DT USERS framework. Given this group of educators was quite familiar with at least one DT process prior to the workshop (e.g., Stanford's d. school, LAUNCH cycle; Spencer, 2017), it is not surprising that they quickly recognized the USERS framework as virtually analogous to these. Overall, educators expressed positive reviews of the USERS framework, commenting that the iterative nature of the framework should be emphasized in graphical and written representations (i.e., portrayed as more of a cycle than a process that begins and ends). To this end, one educator commented on students' propensity to take a linear approach to solving challenges: "Especially in mathematics…when they get to the end, they're like, 'it's done!' Well, does it work? [Are] there problems? Could you improve upon it?" This comment may be an indication that some students will require extra encouragement to move beyond finding "the answer" to considering multiple or new solutions to challenges.

Integrating DT. Three major themes related to integrating DT within the curriculum emerged from the focus group: assessing DT; global competencies and DT; and interdisciplinary learning through DT.

Assessing DT. The most prevalent theme to emerge from the data was the perceived challenge of assessing DT in the classroom. Several educators commented on how integrating DT will affect assessment directly because of the shift away from grading a final product, as opposed to assessing the process of designing and iterating. Some educators suggested potential approaches that educators could use to assess DT, including learning journals, self-reflection, and learning logs. In support of these suggestions, one educator commented: "You're not just assessing that final project they created. They really do need to document their learning journey, and that is the assessment."

Another educator similarly stated that using student documentation as an assessment tool can be empowering: "…ensuring student voice and student choice, so their product can be whatever is comfortable for them to demonstrate their learning." Comments from educators reflected the need for research to establish valid and reliable ways for assessing DT, but to do so in a way that provides learners the flexibility to define success or progress.

Global competencies and DT. Several educators also discussed DT in relation to the larger focus on global competencies and learning beyond classrooms. In relation to the lesson plans, educators discussed several ways to include community groups or academic experts, such as digital human libraries or virtual researcher programs that connect classes with leading scholars without having to travel. One educator stated: "…it's not always leaving your classroom. You can have this authentic experience right in your classroom, but sometimes it is a collaboration and communication with partners." As reflected in this comment, educators were enthusiastic about the potential for community involvement in learning with a DT lens.

Another educator asserted the value of learning beyond the classroom: "…when students do something for the teacher, they don't do their best work, but when they do something that's public-facing, all of a sudden you start seeing some amazing things happen." According to this comment, collaborating with community partners to enhance DT-focused learning can promote global competencies but also positively affect student performance. Another educator reiterated students' positive attitudes elicited by connection to the real world:

> …kids go home and they want to do it, they're excited about it. It's doesn't feel like homework because they're so invested in it. There's a real reason to do this. It's not just because the teacher assigned it and I have to do it.

Comments from educators strongly suggested that one way to cultivate important global competencies among students is to design and implement course materials that integrate a DT framework.

Interdisciplinary learning through DT. Another central theme to emerge from the data was that educators perceived DT as an opportunity for interdisciplinary learning. This was expected, given that the lesson plans reviewed by educators explicitly linked activities to several different subjects. As one educator stated, DT can be a tool for interdisciplinary collaboration: "…integrating across curriculum into social studies, science, math, and language." For example, the "One with Nature" lesson plan was connected to measurement units in mathematics and science, and connected to research showing the benefits of having plants in the classroom (Daly et al., 2010). An emphasis on interdisciplinary studies is in line with the recent push to focus on STEAM (science, technology, engineering, arts, and math) versus only STEM (science, technology, engineering, and mathematics) subjects (Maeda, 2013).

Limitations

The present study was guided by two questions asking how educators understood the DT process and how they perceived DT fitting into their classrooms. To address these questions, we recruited a group of experienced educators to complete an online intake survey and then participate in a focus group. It is of note that we invited educators to participate because of their working knowledge of DT and technology in the classroom. Not surprisingly, educators were quite familiar with some form of the DT process (i.e., were able to define and describe the process), so this likely facilitated the ability to focus on the curriculum content using the DT perspective. Notably, educators' familiarity with integrating technology into the classroom may be considered a reflection of the broader systemic emphasis on student engagement in STEM subjects (Government of Canada, 2014). On the one hand, this specialized focus group allowed us to gain insight from educators on the frontlines of implementing new and emerging technologies into teaching. On the other hand, one limitation is that our findings showing educators' familiarity with DT may not extend to other Canadian educators. Additional research should therefore focus on measuring educators' perceptions of DT to gain a more comprehensive understanding of how educators envision DT in teaching and learning.

An additional limitation of the current work is the small sample size and single focus group. While valuable to understand the perceptions of experienced educators, it must be noted that the data collected here only represents one small subgroup of teaching professionals. Future research should conduct further assessment of how DT might be integrated into teaching among a more diverse and larger group of educators. Furthermore, in the current study we asked educators to review lesson plans in which technology could be utilized. However, such lesson plans are only one method of capturing the DT process in the classroom. Therefore, future studies should also assess alternative methods of integrating DT into learning beyond a structured lesson plan. Given these notable limitations, conclusions from the present work should be interpreted as preliminary insights into how educators see DT being integrated into their practice.

Discussion

Consistent with previous work (Hawthorne et al., 2014), the current focus group perceived some difficulty in assessing DT, but at the same time readily suggested various innovative ways to do so, such as learning logs and student-driven and holistic assessments. These suggestions are in line with previous literature documenting ways to assess DT in education, including project-based assessments (Hawthorne et al., 2014). Like the challenge researchers and educators face in establishing a valid and reliable method for assessing CT (Mueller et al., 2017), the current study supports the notion that assessing DT in educational contexts may be perceived by educators as a challenging feat.

Despite this perceived challenge, the present findings also suggest that integrating DT into teaching and learning can be a means to achieve global competencies like critical thinking, collaboration, and global citizenship (OECD, 2003, 2018; Battelle for Kids, 2019). The educators in our study were familiar with DT to some extent, but it is possible that educators just learning about DT will express similar enthusiasm. Indeed, a foundation of the DT philosophy is human-centrism that seeks to improve constantly to satisfy the users' needs (Plattner et al., 2009). Moreover, it is encouraging that educators easily linked DT with global competencies, given that the emphasis of both of these constructs as being instrumental in future education (Government of Canada, 2014; Howell & O'Donnell, 2017).

In line with previous research showing the positive effects of DT for educators (Carroll et al., 2010), educators in the present study were enthusiastic about how DT presents opportunities for interdisciplinary collaboration. When reviewing our lesson plans, educators frequently drew connections between different subjects such as arts, sciences, social studies, and mathematics. This finding supports work on DT in classrooms spanning multiple subjects (Carroll et al., 2010; Hmelo et al., 2000; Plattner et al., 2009; Roussou et al., 2007). Just as previous research has shown that CT is relevant throughout elementary curricula (Hennessey et al., 2017; Mueller et al., 2017), educators in the current study readily acknowledged the value of DT in linking concepts and content across disciplines that can be useful in research and practice (Anderson & Shattuck, 2012).

Also consistent with previous research (e.g., Rauth et al., 2010), educators in the present study perceived the DT process as one in which they could solve problems using a combination of previously acquired skills, knowledge, and current learning outcomes. Also consistent with Rauth et al. (2010), educators described the potential link between DT and a more flexible approach to problem solving. If educators cultivate a more incremental versus fixed mindset in relation to problem solving, students may experience collateral benefits noted in previous research such as greater persistence on challenging tasks (Yeager & Dweck, 2012).

The current study is timely. Government initiatives and industry efforts are striving to prepare students for success in the 21st century (Government of Canada, 2014; Howell & O'Donnell, 2017; OECD, 2003, 2018; Battelle for Kids, 2019). In Canadian society, where almost all Canadians under the age of 45 use the Internet every day (Statistics Canada, 2017), gaining digital literacy is an appropriate priority. In response to the need for digital literacy, educators have integrated new skills and ways of thinking, including both Computational Thinking and Design Thinking (e.g., Anderson & Shattuck, 2012; Carroll et al., 2010; Dukes & Koch, 2012; Goldman et al., 1998; Hennessey et al., 2017; Hmelo et al., 2000; Mueller et al., 2017; Roussou et al., 2007). Furthermore, researchers have acknowledged the extent to which the education system has been proliferated with terms crossing over from technology like makerspace, coding, and DT (Wiebe et al., 2018). Yet more should be researched about how educators understand emerging educational-technological crossovers like DT or how they see the design process fitting into their practices. This study included a collaborative partnership with an industry partner beyond "training for educators" to include authentic and reciprocal feedback on the content of resource materials for educators in the implementation of DT in the curriculum. Educators and students appreciate the integration of expertise from industry partners to support the pedagogical knowledge and skills of teachers (Willard-Holt et al., 2018).

This study suggests that among some educators, DT is well understood. However, it should be noted that this depth of understanding will likely differ across classrooms, schools, and geographic regions. Additionally, this research illustrates how a DT framework can be successfully applied to curriculum content across multiple disciplines, emphasizing an interdisciplinary approach to solving modern problems. Overall, our findings suggest that many educators will respond positively to integrating DT into their classrooms, but they may also perceive challenges about how to assess learning outcomes. Despite some limitations, the present research demonstrates the fundamental importance in exploring educators' perceptions of DT in the context of teaching and learning.

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