27.2

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27.2 Editorial: Turning tables and challenging perceptions

Kay Stables, Goldsmiths, University of London, UK
Lyndon Buck, Aston University, UK

In this issue of the journal we present six articles each of which, in their own way provide a 'pause for thought', challenging a norm, shifting perspective, suggesting an alternative approach. In preparing this editorial, each article provided something slightly unsettling, but in a good way. How much do we really understand about all aspects of value when young children are drawing? Is taking a subtle approach to research more revealing than a more direct one? What happens if as a researcher your research focuses on researching the research that your students have undertaken? What is revealed when researchers shift the cultural lens through which the research is explored? If design is interdisciplinary why is there not more research exploring liminal spaces opened up by design thinking?

So, this short introduction is in the form of a quiz. Enjoy exploring the articles!

In the first article, *From 3D to 2D: Drawing as documentation and reflection processes by young children*, Asi Kuperman, Ruti Aladjem, David Mioduser, Tel Aviv University Israel and Osnat Dagan, Beit Berl College Israel, provide insights into the ways in which young children make drawings of constructions that they have first built. Much previous research looking at children's drawing has been based on spontaneous, imaginative drawing, or drawing in advance of making. In this fascinating study the authors have turned this approach upside down wherein the making has come first and the purpose of the drawing is reflection and documentation of the constructing, making visible the ability of five and six year olds' to observe detail and provide insight into their understandings of how artefacts work. The researchers conclude that drawing after making can be used as a tool for documentation and refection by your children and that this has the potential to support the development of technological thinking.

The following two articles provide insights into aspects of STEM. The first of these focuses on research to establish the development of a checklist to assist teachers in exploring their own potential gender bias in teaching science and technology, particularly focusing on covert, subtle and unintentional forms of gender bias. In *Are my technology lessons for girls? The Gender Sensitive Education Checklist (GSEC) for teaching Science and Technology* Eva Dierickxa, Kato Luyckx and Jan Ardies, AP University of Applied Sciences and Arts, Belgium used an educational design research method involving both background research and development and a series of development workshops to create the checklist. This involved working with student teachers, practicing teachers, counsellors, teacher educators and technology-experts. The research took account of those working with age ranges from six to sixteen year olds. The aim was to create a tool for educators that would help them discover their own strengths and potential biases and the resulting tool formed a checklist built around four pillars: fundamental critical attitude, the image of technology, guidance & interaction in the lessons and didactical methods. The research presented in this article focuses more on the development of the tool than on the effectiveness of the tool – this aspect is still to be addressed. But from the depth and extent of the iterative design research methods underpinning the research, the checklist looks to be a powerful tool in supporting teachers to reflect on and develop their teaching.

In the second STEM focused article Susanne Engström of KTH Royal Institute of Technology, Sweden *From a teacher student's view – how STEM-actors have impact on teacher education and teaching in STEM* reports on a study in which eighty five student teachers preparing to become lower or upper secondary teachers in Swedish schools became researchers. Their task was investigating STEM activities taking place outside of a formal education system, led by 'STEM-actors', for example in maker spaces or science centres. For the student teachers this was an assignment where they were required to read research related to STEM teaching in informal education settings and then observe and interview four different STEM-actors and prepare written reflections, a presentation and conclusions. The work undertaken by the students then became a set of case studies analysed by the author. The analysis provides a wealth of insight both into the approach taken and to the perceptions of the students evident in the case studies. At an overarching level the analysis indicated that the student teachers were generally enthused by what they saw and that pre-conceived notions of shortcomings in formal schooling (although not that of the student teachers themselves) required more external STEM-actors to be involved. They identified the importance of teaching being engaging, fun and interesting but were not convinced that practical work was more important than the theoretical foundations that were missing. The article has considerable value both in the sharing of the pedagogic approach to a student teacher research project and also to the research analysis made by the teacher educator of the outcomes of student teachers' learning through undertaking a research project.

The next article focuses on teacher attitudes to curriculum change. Anriet Van Deventer, University of Pretoria, South Africa draws from PhD research on *Teachers' attitudes towards the amendments in the Design curriculum: a critical overview of the approach and findings of the study*. Teachers world-wide are routinely subjected to changes in the curriculum that they teach and, whether reactions to changes are positive or negative, the value of consultation with teachers in advance of changes is often not recognised. The research presented in this article looks at this issue from the teacher's perspective and, of particular significance, from a culturally relevant philosophy. The research focuses on changes to the formal Design Education curriculum of Grade 10 and 11 in South Africa and is viewed through the ideological lens of Ubuntu – an African democratic philosophy underpinned by collective identity and values such as kindness, compassion respect for others and benevolence. In the words of the author "we used the *Ubuntu* ideology as the main ethical criterion to understand and assess the humanity of the Design teachers in terms of their actual teaching, their theoretical frameworks, personal concepts, beliefs, and emotions." The article provides detailed information on the South African curriculum requirements for normal assessment in design education and changes that have been introduced in a somewhat abrupt fashion. Eight teachers, varying in age, qualification and experience, from seven schools completed a questionnaire focusing on attitudes to change both generally and in relation to the curriculum change and were then interviewed to gain more detailed insight. Although the overall responses to the changes were positive, further detail indicates their views were more mixed including, for example, that half of the teachers considered change to be good, but that more review was needed and teachers should be consulted in advance of change being implemented. Within the recommendations teachers are seen as the primary stakeholders and the research highlights the need for greater recognition of teacher voice within the philosophy of Ubuntu when change is being discussed.

Continuing with a theme of curriculum change, a different lens is presented by William J. Gibbs, Duquesne University, USA. In *Design Thinking, An Examination of Epistemological Frameworks in an Area of Academic Study*, Design Thinking is explored as a framework to aid curriculum design in the context of digital media programmes in Higher Education. Taking a case study approach within a single university setting, Design Thinking was utilised as a framework to structure evaluation of a programme and curriculum in advance of re-designing the curriculum. This detailed case study highlights the potential of drawing on the views of multiple stakeholders who may not be designers but can engage in a Design Thinking approach. The article provides considerable detail on background research and the aspect undertaken, but at the centre is the use of Design Thinking in iterating between defining an aspect to be assessed and then ideating in response to that which is being defined. Researching the approach whilst enacting the approach also highlighted areas for developing a Design Thinking approach that was not being utilised for developing a solution for an external client but for an internal team who were both designer and client. This highly detailed case study did produce insights into challenges that the process presented, not least the time that needed to be committed to the project. But it also provides valuable insight into using the affordances of a process of Design Thinking and the possibility to customise as and when needed.

The final article in this issue is a second article with a base in Design Thinking, *Mapping current research and future directions of Design Literacy with systematic quantitative literature review (SQLR)* comes from Julius Cesar Bolinas, Griffith University, Australia. The article has two distinct dimensions. First the article is constituted as a Systematic, Quantitative Literature Review (SQLR). Second is the topic under review – Design Literacy. The particular methodology for conducting the literature review is aimed at defining the characteristics of Design Literacy and mapping the direction this research. In undertaking this approach he provides insights into his perception of the advantages of SQLR over a narrative approach. The author also focuses on the universal educational value of design literacy for developing modes of cognition as well as its specific role in the context of design, for example in supporting solving real-world, wicked problems. In exploring definitions a range of authors and approaches are presented that broaden the area in terms of phases of education where definitions appear and differences in terminology, for example between design thinking, designerly thinking, designerly ways of knowing and designerly stance. The article provides a clear account of using the methodology, including the ways in which he adapted aspects of his approach as his research progressed and a justification for how and why literature was included or not. The methodology provides insights into ways of analysing and quantifying literature that was found, enabling an overview of how much, or how little, literature was apparent and in what sectors of education.

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From 3D to 2D: Drawing as documentation and reflection processes by young children

Asi Kuperman, Tel Aviv University, Israel
Ruthi Aladjem, Tel Aviv University, Israel
Osnat Dagan, Beit Berl College, Israel
David Mioduser, Tel Aviv University, Israel

Abstract

The purpose of this study is to gain a deep understanding of kindergarten children's drawings as a form of documentation of their work, of their ability to notice and depict substantial details, as well as their understanding of how objects in the world "work". In the study, we examined drawings created by kindergarten children for documenting artefacts they previously constructed. The drawing process demands the cognitive transition from the perception of the 3D object to its 2D drawing. Most theoretical and research work conducted over the years focused on children's free, intuitive and/or spontaneous drawing. As well, most studies focused on children drawings of given objects, even their copy of drawings of objects, or on free representation of ideas or feelings. In this study, we addressed two aspects that differ from the foci of previous work: (a) children drew an object they have constructed; and (b) the drawing has a functional purpose (i.e., documentation) as part of a design task. The study participants included 30 kindergarten children, aged 5-6. During freeform play, the children produced constructions using a building kit and documented these in drawings. A total of 39 constructions and corresponding drawings were analyzed. Data analysis was conducted to examine the characteristics of children's drawings, as well as the relationship between the features of the constructions and the corresponding drawings. The insights emerging from the study indicate that drawing can serve as a tool for documentation and reflection by kindergarten children and may support the development of technological thinking.

Keywords

Documentation, Reflection, Drawing, Sketching, Construction, Kindergarten Children, Technological Thinking

Introduction

The purpose of this study is to gain a deep understanding of kindergarten children's drawings as a form of documentation of their work, of their ability to notice and depict substantial details, as well as their understanding of how objects in the world "work".

The study is part of a long-term research program based on the constructionist "Design and Learning" (D&L) model, designed to advance kindergarten children's design and technological thinking (Mioduser, 2009; Mioduser, Kuperman & Levy, 2012). The learning program has been implemented in kindergartens for over a decade, coupled with a comprehensive curriculum, a teacher training module as well as a robotic programming environment. "Designing and sketching" is one of the six strands that comprise the curriculum (Dagan, Kuperman & Mioduser, 2012; Aladjem, Kuperman & Mioduser 2020).

A core goal of the learning program is to foster design thinking - an iterative process in which designers toggle back and forth between analysis and synthesis and operate in both the concrete and abstract worlds (Beckman & Barry, 2008). Design thinking involves procedural knowledge (know-how), conceptual knowledge (know-what) and declarative knowledge, as well as metacognitive processes and analysis, synthesis, and evaluation skills (Kimbell et al. 1991; McCormick, 2004; Mioduser & Dagan 2007; Stevenson, 2004; Kimbell & Stables, 2007; Stables, 2020)

The focus of the study reported here is a design and documentation activity in which children are first asked to construct an artefact using a building kit (LEGO and LEGO Duplo blocks), and then to document their constructions by generating a detailed sketch.

The research questions on which we report in this paper focus on: (a) the concrete properties of the drawings generated by the children for depicting the object they constructed by themselves; and (b) children's knowledge as reflected in the drawings concerning artifacts' static and dynamic features:

1. What types of constructions (and corresponding drawings) did the children produce?
2. How accurately do the drawings depict the structural and dynamic properties of the constructions?
3. What perspectives and projections did children use while documenting the constructed objects (e.g., drawing from the side, from above, mixed views)?
4. Is it possible to replicate the constructions from the drawings?

An all-embracing question: What do children (in our study) know when they "draw what they know"? (Elaboration on this fifth question will be presented in the discussion section).

The following review briefly surveys the background for the study concerning designing and drawing by kindergarten children.

Theoretical background

Construction kits in the kindergarten

Children construct knowledge through being involved in a wide range of experiences, e.g., participating in games, in social interactions, inquiring about phenomena in the environment, and behaving within it (Piaget & Inhelder, 1969). Active experience with objects, and their operation, is crucial for developing concrete and abstract thinking and facilitates the transition from direct manipulations to formal and abstract operations (Resnik, 2007).

Construction and assembly are an integral part of the kindergarten experience. Engaging in assembly activities is a meaningful part of the children's cognitive, social, and emotional development, encouraging curiosity and active participation in spatial problem-solving (Bagiati & Envangelou, 2016; Newburger & Vaughan, 2006; McGarvey et al., 2018; Parkinson, 2017; Wellhousen & Kieff, 2001). Studies among young children demonstrate that problem-solving tasks with building blocks contribute to spatial thinking (Bagiati & Envangelou, 2016). Problem-solving while constructing involves estimation and relativity - as children should estimate, e.g., the number, size or required function of pieces to be included in a structure and apply concepts of spatial relation and configuration (e.g., near/far, up/down).

Educational construction kits have been in use for about two centuries (Zuckerman, 2006) - since the systematic use of Frederik Froebel blocks' and 19th century alphabetic blocks up to the endless types of construction kits currently in use (see Provenzo & Brett, 1983, interesting historical account of blocks kits for children). Construction kits are considered to be effective learning tools that enhance cognitive, social, emotional and sensitivity skills. These kits afford construction options and pose constraints that may promote curiosity and foster the ability to design and solve spatial problems (Parkinson, 2017). The rapid development of spatial skills occurs between the ages of 5-8 and can be facilitated with activities such as building with construction kits, playing 3D computer games, copying, drawing and more (McGarvey et al., 2018). Furthermore, designing structures with building blocks requires creativity and the development of a sense of esthetics, motivating children to manipulate changes in size, appearance, and stability of the structure. Moreover, formal knowledge (e.g., physics laws - balance, gravity- or arithmetic procedures) may be learned through practice (Bagiati & Envangelou, 2016). Studies also show that children develop physical, social, creativity and problem-solving abilities during free blocks-construction play (Newburger & Vaughan, 2006).

Children's Drawing

Research focusing on children's drawings characteristics, as well as on the development of children's ability to represent aspects of their inner and outer world, is being conducted for over a century. However, two issues characterizing the vast body of knowledge generated are relevant for our study: (a) Seminal research work and comprehensive accounts of the development of children's drawing were conducted and published during the previous century, mostly until the 80's and 90's. Research since then has addressed highly interesting but specific aspects of drawing in varied contexts. (b) Research on children's drawing for technical or functional purposes, as part of design processes, is definitely scarce.

A detailed presentation of published work on the development of children's drawing is beyond the scope of this paper – for this we can refer to the comprehensive review of the history of theoretical and research work (the foundations) published by Strommen (1988), or to the background section in the recently published paper by Sawyer & Goldstein (2019). Undoubtedly, several important insights stemming from this long research endeavor are highly relevant to our study.

A substantial issue is the attempt to trace the developmental path of children's representational ability, and to identify stages in this development based on salient variables and characteristics in the drawings. The developmental process has been characterized in different ways, vis-à-vis the theoretical stance adopted.

Emphasis on the content of the drawings, and the intellectual and conceptual aspects involved in their production, view these as external representations of thought. In this theoretical approach, drawings do reflect children's mental images of aspects of the world or conceptual knowledge. Early stages in the development of children's drawing are synthesized in the claim: "children draw what they know rather than what they see". Advanced stages seem to rely increasingly on perceptual inputs affecting the gradual construction of complex representational schemas externalized in the drawings. The developmental path thus advances from "intellectual realism" (e.g., evident in the inclusion of "impossible views" in the drawings) to "visual realism" (e.g., guided by perceptual data), as formulated in Luquet's pioneering work (1927).

An alternative developmental framework focuses on the specific components used in the drawings, and the skills and strategies implemented to produce these. Here the answer to the question "what develops" emphasizes the representational resources used by the children, (e.g., graphical units, recurring schemas), spatial strategies (e.g., perspective taking, spatial configuration) and production-skills (e.g., visuo-motor abilities). The development path is depicted in terms of the increasing mastery and refinement of abilities and strategies as well as the scope of the tool box used by the children in their drawings. (e.g., Ackermann, 1996; Karmiloff-Smith, 1990.

A third theoretical framework conceives drawings as a systemic product, integrating among different layers: cognitive/intellectual/conceptual (what is represented); resources/skills/strategies implemented (how the content is represented); socio-cultural parameters (context for the production of the representation). The last layer refers to aspects affecting (or comprising) the drawings such as culturally-accepted features (e.g., use of conventional schemas such as the square+triangle scheme for a house, or color, gestures and configuration conventions in religious art – Arnheim, 1997; Picard & Durand, 2005); externally defined functions (e.g., as in curricular tasks, or in imposed functions such as drawing for planning or manufacturing); or socially-convened constraints. This comprehensive-systemic view of developmental paths is rooted in a range of theoretical and research work over the years, including systems, cognitive development, art or socio-cultural theories.

In the study reported in this paper we rely on this vast body of knowledge while focusing on a specific genre of drawings: children's technical drawing.

Children's technical drawing

In contrast with the extensive research work conducted for many decades on children's free and expressive drawings, inquiry on children's drawings with functional (and technical) purposes has been scarce.

In design thinking, drawing is a key element for visualizing ideas, communicating them (to oneself and others), and exploring new ideas (Lawson, 2004; Hope 2008; Sung, Kelley and Han, 2019). Recognizing that children draw their mental image of an object, the image in their mind's eye (Ferguson, 1994), and not solely their visual perception of it, is pivotal to understand how they represent aspects of the world. Research on drawings produced for planning and construction, showed that most young children are able to draw a 2D design, but many of them had difficulty using their drawings/plans to produce actual constructions (Anning, 1997; Anning, 2008; Fleer, 2000; Hope, 2008; Hope 2017).

Representational technics and resources for depicting 3D objects in two dimensional drawings were developed in Renaissance times (e.g., linear perspective, cutaway and exploded views, or drawing apparatuses), serving artistic and technical representations as well (Ferguson, 1994). Since then, a wide range of technics and conventions (and currently software tools) has been developed for supporting technical and engineering work. Spatial intervention studies with engineering students emphasize the importance of generating different representations of 3D models created/to-be-created, e.g., a coded plan (2D representation on a grid or isometric paper); orthographic drawings (top-front-side); or isometric sketches (perspective drawings). While young children can perform the first and the second type of drawings, they have difficulties with the third (McGarvey et al., 2018). These skills are developed as part of building with imposed constraints, and require flexibility of thinking allowing moving between 2D representations and 3D constructions. The creation of these representations demands multiple perspective-taking thought in different forms of drawing and are an essential aspect of spatial skills development (Ackermann, 1996; McGarvey et al., 2018).

Piaget and Inhelder's (1971) distinction between reproductive (R) and anticipatory (A) images is highly important for the discussion of children's technical drawing. 'R' refers to the capability to represent in images something already perceived (as in documenting an object). 'A' implies imagining a yet non-existing object (as in planning). Moreover, they deepen the analysis to refer to either 'R' or 'A' images depicting static (S), Kinetic (K) or transformation (T) states. Their findings show that while 'RS' images are produced at early stages in children's development (preoperational stage), anticipatory images in general and either reproductive or anticipatory images of 'K' and 'T' processes in particular are produced only by the age of 7-8 (operational stage). These observations are relevant for addressing children's technical drawing in design tasks, where they are asked to represent constructed artefacts (most often including mechanical-kinetic components) and even the transformations resulting from their functioning (e.g., movement, changing relative position of components) - as in our study.

In this study, we consider drawings as an expression of children's cognitive development and their ability to manipulate symbols, meaning the way they use signifiers to represent signified static and kinetic objects and their transformation states (Vygotsky, 1980; DeLoache, 2004).

Conceptual framework for the study

Grounded in relevant aspects of the body of knowledge briefly surveyed, our research questions and variables address children's drawing in a specific context: documenting an object following its construction.

Two important characteristics in our study contrast with the setting and variables of most of the surveyed previous research: Children's' involvement in constructing the represented object, and the functional aim of the drawing.

In most studies children are requested to draw existing objects, many times even to copy drawings of objects or manipulate cards with drawn components. In our study children are actively involved in constructing the object they are required to draw. Thus, critical issues immediately emerge, vis a vis the conclusions of previous research, e.g., how "drawing what they know" is affected by the fact that "what they know" is constructed while constructing the object (the 'constructionist way')? Will this imply also in this study an early and biased stage of representation less accurate than the "visual-realism" stage as traditionally claimed?

The second differing characteristic relates to the functional goal of the drawing. In most research work children are requested to represent aspects of reality or concepts. They either observe models or objects or the are asked to represent concepts or feelings. All these pertain to the genre of free or expressive drawings without any constrain related to a function to be fulfilled. In our study, as in any study related to design or engineering processes, the drawing activity play a functional role. We asked children to create drawings that document their constructed objects, to depict as good as possible the objects structure, components, or any other important property. Moreover, we aimed to examine whether the drawing can guide the construction of the depicted object (i.e., a planning function).

Methodology

Research setting and participants

Participants in the study were 30 children aged 5-6 from average socio-economic-status (SES) homes attending compulsory kindergarten in the center of Israel. The activities conducted during the research were part of the curriculum entitled "Developing technological thinking in early childhood education" (Mioduser, Kuperman & Levi 2012).

Concerning ethical issues: the kindergarten was defined as "experimental" by the Ministry of Education and all necessary permits to conduct research were granted, including parents informed consent. Data collected did not include audio or video recordings and any personal identity information. Photographed constructions and drawings constitute the data base of the study.

In the specific activities, children created constructions using LEGO and LEGO Duplo bricks, as part of their playtime in the kindergarten. The children did not receive instructions or mediation from the staff before or during the construction process. After constructing their artifact, the children were asked to produce drawings of their creations, using a plain sheet of paper, pencils, crayons, and markers of their choice. They were free to draw according to their understanding. Thirty-nine constructions and corresponding drawings were produced. Additionally, children were encouraged to describe their constructions - the teacher documented their verbal explanations if they chose to do so. As a result, 21 of the 39 drawings collected were complemented by verbal descriptions. The constructions and sketches produced, documented and photographed, constituted the database of this study.

Data analysis

The analysis of the findings was conducted following qualitative methods, using a grounded (bottom-up) paradigm. The definition of the categories was grounded on: (a) the actual data collected – children drawings; and (b) previous work, in particular developmental research, as surveyed in the background section (e.g., in Piaget & Inhelder, 1971; Karmiloff-Smith, 1990; Ackermann, 1996).

The analysis included several phases:

1. Defining the potential classing criteria emerging from the drawings and photographic documentation of the constructions.
2. Analyzing the (photographed) constructions according to the defined categories (e.g., looking at aspects such as static or moving parts; or technological mechanisms).
3. Transcripts of descriptions (if available) were also analyzed to shed light on children's intentions and decisions while building.
4. Analyzing the drawings according to representational parameters defined (e.g., match with the physical construction; representation of parts; projections).

Criteria and categories of analysis

For the first research question, three categories for classing the constructions and drawings were defined. Examining the drawings, a clear-cut variable emerged: whether they included mechanical or movement related components and moreover, compounds that enable the artifact as a whole to move and navigate in space. Although conceptually these data-grounded categories correspond to the developmental paths depicted in the literature on children's representations, we do not refer to them as ordinal or hierarchical. The categories were:

1. **Static**. No dynamic mechanisms are present and there is no evidence in children's explanations of any intention to build something that can move or has movement.
2. **Semi-dynamic**. These contain technological mechanisms that generate some level of movement (levers, relays, axes, gears, etc.). In addition, the children described the construction as one that "does" something, with evidence of parts that enable movement (e.g., wheels, axes).
3. **Dynamic**. The entire construction has mobile compounds or can move or travel.

For the second research question each sketch was analyzed focusing on the following characteristics:

- General level of detail in the sketch.
- Degree of accuracy of scale and proportion between parts
- Degree of accuracy in portraying construction details including emphasis in prominent elements
- whether a human figure is included

For the third research question, we looked at the perspectives and projections included in the drawings, e.g., top, side or mixed projections.

For the fourth research question, we examined the extent to what the representation can serve as guide for reconstructing the depicted object.

Findings

The findings are presented in the following sections according to the research questions.

Q1: Mechanical/dynamic aspects in the constructions and corresponding drawings

Thirty-nine objects were constructed by the children and depicted in the drawings. Concerning static/dynamic we classed the constructed objects in three categories: *S* (structural) – mainly structures and static objects; *SD (semi-dynamic)* – including some mechanical and moving elements; *D* (dynamic) – including large mechanical compounds or even navigation capabilities for the whole artifact. A similar number of constructions (and drawings) of each type has been produced by the participants, about a third in each category (Table 1).

An example of a static object appears in Figure 5. The child built a tall tower – a fairly complex structure including the repeated use of one modular piece and symmetric design. All these are clearly visible in the drawing documenting the tower.

An example of a semi-dynamic construction appears in Figure 4. Attached to the static structure is a crane-like mechanism aimed to lift objects. The drawing of it is quite schematic, however emphasizing the core structural component of the dynamic compound, i.e., the gears. Children's verbal descriptions often unveiled aspects of their perceptions not included in the drawings. For the construction in Figure 4, the child explained: "I turn the stick then the gear turns as well ... the red piece does not move ... the 'fastener' grasps". Moreover, there is reference to purpose or functional aspects: "to catch fish ... to save someone from drowning ... I made a crane".

An example of a fully dynamic construction us shown in Figures 2, 3 and 7. In these artefacts all compounds (structural and dynamic) contribute to fulfill its defining function: to move and navigate in space. Correspondingly, the salient representational unit in the drawings are the wheels and axes, forcing their inclusion even in projections in which these would be out of sight.

Children are used to construct using many kinds of building kits at home and in the kindergarten. Thus, we can assume that they brought previous building schemas and knowledge into the task in our study. When faced with the free-construction (not directed) task, we can also assume that the inputs triggering the construction of semi-dynamic and dynamic objects were not only previous schemas but also the mechanical pieces at hand in the kits, e.g., wheels, axes, gears, hooks. These may have acted as cue for the inclusion of mechanical compounds in the objects and even for creating the whole construction (as in the cars).

Q2: Degree of accuracy in representing structural aspects

In this section we examine the extent to which the drawing accurately represents the construction. This includes an analysis of the level of detail, of proportionality, and whether all important details of the construction are represented including mechanisms and additional pieces (e.g., human figures).

Level of detail of the drawing

The degree of detail in the drawings ranges from highly-detailed (showing even the bumps on the LEGO bricks or details on the wheels), to these that only show the contour of the construction. Of the 11 sketches of static constructions, seven were contour-only and four were detailed (Figure 1). For nine of the 15 semi-dynamic constructions, the drawing show only outlines, sometimes a few bricks are represented. Other details such as holes in the blocks were scarcely drawn. In the more detailed drawings, particular prominence is given to mechanisms (Figure 4). Axles, hooks with ropes and gears do appear, even if the sketch is minimalistic. Most sketches of the dynamic constructions (9 out of 13) consisted of outlines. Four of them had more detail. Like for the semi-dynamic constructions - in these the moving parts are always shown, even if not in detail (Figure 7).

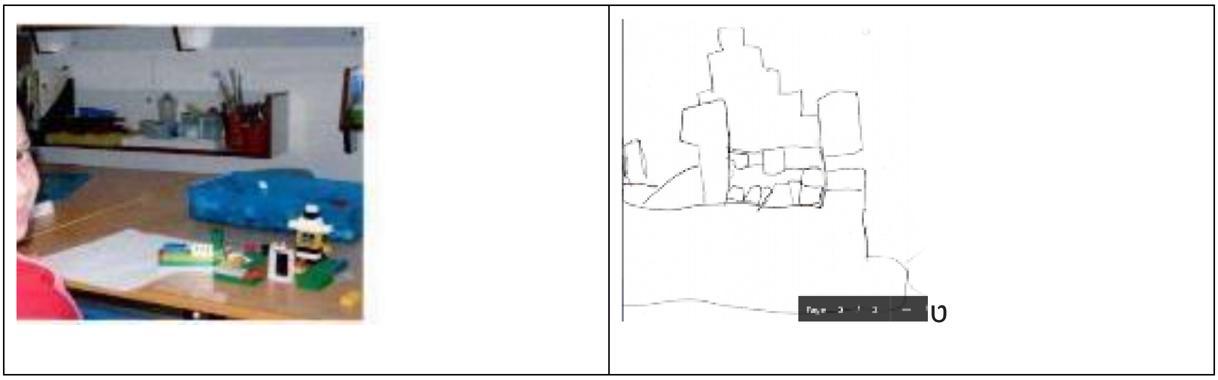

Figure 1: Sketch of a static construction – contour-only

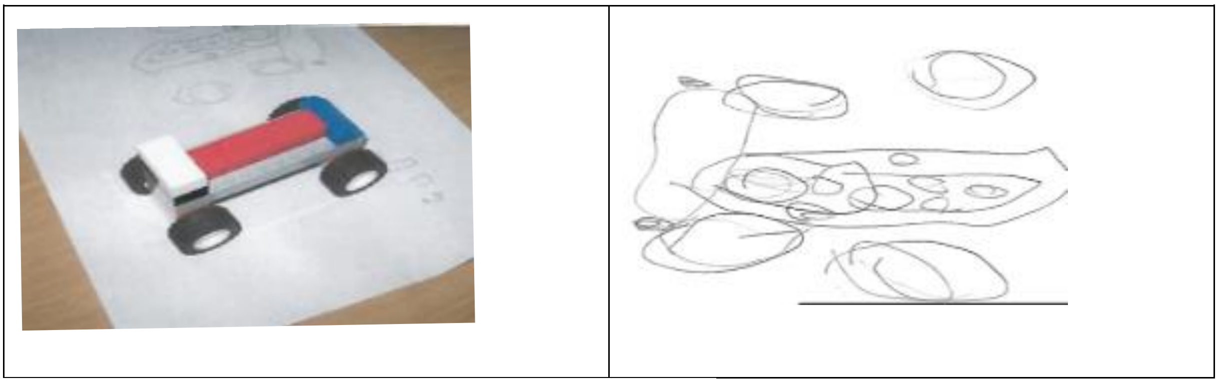

Figure 2: Sketch of a dynamic construction with details

Figure 3: Side view of a car with four wheels

Figure 4: Sketch including a technological mechanism

Degree of accuracy of scale and proportion

Ten of the 11 static sketches showed accurate proportions between the different parts as well as between their size on paper and their actual size (Figures 1, 5). In all 15 of the semi-dynamic sketches the proportions matched the physical construction. In the sketches of dynamic artefacts, however, although the proportions between the parts were appropriate, if a human-figure was included, its representation was not proportional – either too small or too big.

Degree of accuracy in representing construction details

The extent to which details were included in the sketches was very varied, ranging from having only contours with no details at all, to very detailed drawings showing the gears teeth and bumps in the LEGO bricks.

All 15 semi-dynamic sketches portrayed the technological mechanisms, even when other elements were not fully detailed. In the dynamic sketches, the wheels always appeared as full circles, i.e., from a side view, even in the top-view sketches. Sometimes all four wheels were sketched, even though only two are visible from the side (see Figures 2, 3, 7).

Concerning the inclusion of human figures in the sketches - in the 11 static sketches only one has a figure both in the physical construction and in the sketch. In the semi-dynamic category, eight of the 15 physical constructions had a human figure and in seven of these the figure also appeared in the sketch. A human figure appeared in six of the dynamic constructions and their respective sketches. Moreover, one of these sketches included an additional figure (a passenger next to the driver) that does not appear in the actual construction.

Q3: Perspectives and projections in the representations

When drawing a 3D object, designers/engineers usually do so from a number of perspectives in order to accurately represent the object in its entirety, from all sides (Ferguson, 1994). In a single sketch one must choose an angle that better reflects the construction. Analysis of the sketches (see Table 1) shows that 18 of them show a side view and eight show a top view. The remaining 13 sketches comprise mixed views, i.e., looking at the construction from several angles or a combination of a side view and a top view. The sketches with mixed views always contained mechanisms, (i.e., they belonged to the dynamic and semi-dynamic categories but not to the static category).

By construction categories, we saw that in sketches of static constructions, 6 were drawn from a side view and 5 from a top view. In the semi-dynamic constructions’ sketches, 7 out of 15 were drawn from a side view and 8 with mixed views. In the dynamic-construction sketches 5 were drawn from a side view, 3 from a top view, and 5 with mixed views.

Furthermore, the sketches of tall constructions were almost always drawn from a side view, whereas when the construction is flat the tendency was to show a top view.

The sketch of the tower (Figure 5) emphasizes its height and clearly represent its structural sections (a topic also mentioned in the child’s verbal description). From above, this aspect of the construction would not be visible.

In sketches of constructions that are spread out and flat, the components and important parts can be seen only from above, as they are shown in the drawings. In Figure 6 (depicting a dynamic construction) though mainly a top view, all wheels were drawn from the side view.

Table 1: Constructions and drawings by category and view

Category / View	Side view	Top view	Mixed view	Total
Static	6	5	-	11
Semi-dynamic	7	-	8	15
Dynamic	5	3	5	13
Total	18	8	13	39

Figure 5: Side-view depiction of a static construction

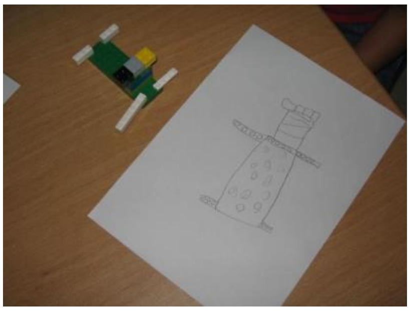

Figure 6: A Top-view sketch

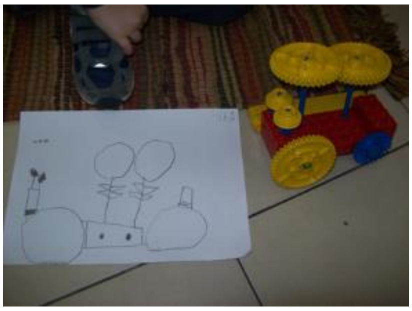

Figure 7: Mixed-view sketch

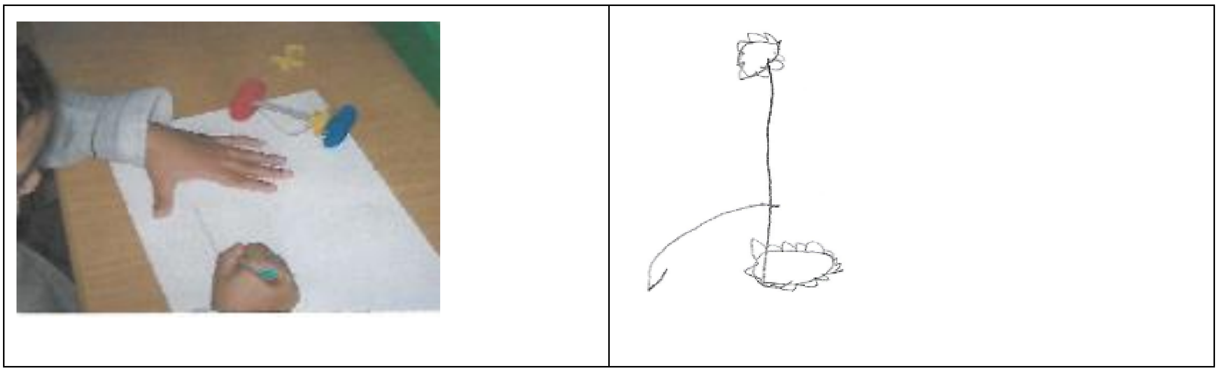

Figure 8: A simple construction that can be recreated from the sketch

Q4: The possibility to replicate the construction from the drawings

Analysis of the possibility to recreate the construction from the sketches showed that although some of are fairly accurate, even containing detailed information, it is hard to replicate the constructions from the representations of the objects. Evidently, the more components in the construction, the lower the possibility to reconstruct it. In fact, only three out of the 39 could be reconstructed solely based on the sketches (e.g., Figure 8).

Summary of key findings

With the purpose to bridge between the data level of the study (detailed above) and the discussion and implications level, we present in the following a mid-level (undetailed) summary of the data collected:

- Children's previous experience with building kits (e.g., building schemas and knowledge), as well as the presence of mechanical pieces in the kits (e.g., wheels, axes), affected their performance in the task and the constructions created.
- Drawings of S and SD constructions: mechanisms and compounds do appear and moving parts are always shown, even if not in full detail.
- Drawings of D constructions: Wheels and axes were the salient representational unit and were included even in projections in which these would be out of sight.
- Most drawings in all categories depicted the artefacts by their contour.
- Proportions: Most sketches showed accurate proportions between the different parts as well as between their size on paper and their actual size. The only exception were non-proportional representations of human figures.
- Accuracy and detail of the representations: a wide range of levels was observed, from contour-only and undetailed to highly detailed drawings.
- Projections: Sketches of tall constructions were usually drawn from a side view, whereas in flat constructions is the tendency was to show these from the top view. Sketches mixing viewpoints always contained mechanisms.
- Replication: For most sketches, we found hard to replicate the constructions from the drawings.

Discussion

Building and assembly activities have become a vital part of the kindergarten curriculum, due to their importance to the child's growth and development (Parkinson, 2017). In our study, participants were asked to document their free constructions in a 2D drawing - an activity which requires a cognitive shift from three dimensional to two-dimensional thinking (McGarvey et al., 2018). Our findings suggest that drawing as means for documentation, which is not typically part of the kindergarten curricular repertoire, has implications for supporting the development of technological and engineering thinking as well as representational skills and strategies for functional (not only expressive) purposes.

As part of the activity, the children freely created 3D constructions and then represented them in 2D form. The process involved "translating" the mental image of an object (about to be built) into a 3D construction, then depicting the constructed object in a 2D sketch (Anning, 2008; McGarvey et al., 2018). In this type of "engineering" sketch, no decorative or secondary elements unrelated to core properties of the construction are included (Lane, 2018). The creation of the 2D depiction requires paying attention to structural and mechanical aspects and conducting iterations between the representation and the actual construction. It typically begins by focusing on the most important components, and then move on to the less important ones. In fact, children are abstractly representing their 3D constructions, using a novel and functional language for drawing - a representational mode that is not part of the regular kindergarten curriculum or experience. In the following, we discuss a range of strategies used by the children to cope with the challenge of representing a 3D object in a 2D sketch.

- *Choosing a view*. Representing a 3D model in a 2D drawing requires a choice of a view (e.g., top, side). We found that a side view was chosen mainly for tall constructions, whereas a top view was used for flat ones. Sketches with mixed views (side and top) were found mainly for dynamic constructions, e.g., these containing wheels, where the wheels were drawn as a full round circle, even when the rest of the vehicle was represented from a top view. Luquet (1927), noted that combining perspectives results from the conflict between wanting to show the wheels from the top and showing them in full. This can be viewed as an example of a problem-solving strategy, where the solution involves changing the vantage point and combining perspectives.
  The ability to imagine what an object would look like from different points of view is considered a core component of the multi-skill construct of human spatial ability (Eilam & Alon, 2019). Ackermann (1996, Pp. 5) pointed out that the perspective-taking ability involves "*objectifying one's own view of the object and anticipating that moving to another station point results in specific changes in its presentation. In other words, perspective-taking involves both differentiation and coordination of viewpoints*" while understanding that these relate to the same object. "*Viewpoints are lenses, and lenses transform reality in specific ways*" (Ackermann, 1996). Given the functional purpose of the drawing, children in our study chose "lenses" guided by their understanding of what core features of the objects should be drawn to represent it at its best (e.g., structural height, mechanical compounds). In addition, they used "combined lenses" if features pertaining to different vantage points were considered essential for representing efficiently the object (e.g., four wheels in a vehicle).
- *Representing proportions*. The accurate representation of proportions in both number and size, requires an understanding of relativity and scale (McGarvey et al., 2018). Luquet (1927), posited that young children are not capable of such understanding and that drawing each detail is independent, without conception of different items' relative sizes and distances from each other. In our study, most drawings show appropriate proportions when depicting parts of the construction (the only exception is the human

figure), indicating that children have at least a basic understanding of correct proportions.

- *Representing mechanisms and internal components*. The challenge faced by the children was how to depict the mechanism and its movement in a static 2D representation. We found that all the drawings of semi-dynamic constructions have representations of the dynamic mechanisms, and that the drawings of the full dynamic constructions included the elements enabling the whole artefact movement (e.g., wheels and tires). Since planning and constructing mechanisms and movement compounds require engineering-related thinking, their representation in the drawings might indicate children's awareness of the thinking/problem-solving processes that led the construction. For producing a sound representation, children's' drawing solutions included often-times what can be seen as "violations" of (correct) realistic drawing, e.g., inclusion of 'insides' or mixing views. Actually, these are resources that allow a better communication of the constructions features within the constraints of 2D drawing. Children are less worried about the correctness of the drawing than about its documentative/communicative function.
- *The social/functional layer* (the perceived reason d'etre of the artefact). It seems obvious that the object constructed has robust linkage with the child's inner world and life experience. Artefacts fulfill functions and these, as well as their representations, include components that reflect this linkage. A clear example in children's products was the incorporation of human figures (included in the construction kits) – apparently a non-necessary element as opposed to key structural or mechanical components. Where a human figure was included in the construction, it always was represented in the drawing as well. Actually, the human figure constitutes a connection between the child's experience and the construction. The figures play explicit social/functional roles: they are drivers, passengers (sit aside the drivers), or operators of the mechanical device. By incorporating this social/emotional layer to the constructions and drawings, these became objects for symbolic play and expression of children perceptions and thoughts about world situations. Un their verbal descriptions explicit allusion to functions fulfilled complemented the representation, e.g., "I've built a truck that collects bottles, classifies them and takes them back to the factory" ... "this is a 'grasping truck' – it grasps garbage cans and collects the garbage with the hook".

What do children know when they 'draw what they know'?

Almost a century ago, Luquet (1927) noted in his pioneering work, that young children solve the problem of representing 3D reality in 2D drawings through 'intellectual realism', meaning that children "draw what they know, rather than what they see". Only around the age of eight they reach the stage of 'visual realism' in which they can draw reality as is (relying on perceptual data). In the current study, we found that in contrast with Luquet's assumptions, kindergarten children (aged 5) do in fact show capabilities that correspond with the later "visual realism" stage. As well, in terms of Piaget & Inhelder (1971) theory of mental imagery development, we found that children were able to represent reproductive (R) static and kinetic (S, K) features of the artefacts at an earlier age level than the one in their stages' depiction. We suggest that these findings stem from the fact that in the activity in our research, children constructed their own 3D objects and then drew them - thus we assume that their mental image of the 3D object was loaded with a large amount of visual information gained during the construction phase.

Based on these observations, we would like to formulate a different interpretation of the claim: "they draw what they know". What do children know? Undoubtedly, as stated in most theories surveyed, children's mental images are the result of factors such as, e.g., developmental affordances and constraints; life experience (gained through the very immersion in an artefacts-saturated environment); internalization of social constructs (such as canonical or prototypical visual schemas); formal schemas acquired through schooling. However, taking a constructivist/constructionist perspective, in addition to the above factors "what they know" is conceived as a knowledge construction process in which the learner plays the crucial role of active constructor of her/his knowledge – emphasis on "active". What children know, instead of being molded solely by developmental forces, by schooling or the mere (passive) immersion in a nurturing environment, is the result of an active and interactive construction process.

Concerning our questions about the visual knowledge and schemas used by children to produce their drawings, we suggest that these are constructed in iterative process while dealing with the challenge of constructing the real object. In the process, a large amount of real-world knowledge is constructed. Thus, drawing "what they know" is no longer an inferior developmental stage on the way to the "higher" visual realism stage. In constructing the inner repertoire of knowledge and schemas while constructing real objects in the world, "drawing what they know" now becomes a very sophisticated and complex representational activity. Children know a lot, and they know what they know due to their intimate acquaintance with the represented structures and mechanisms (their own constructions), and to their active role as constructors of both their inner (in their mind) knowledge and the outer (in the world) object.

Concerning technical or engineering-like drawing, the above working hypothesis allow us to look differently at the representational resources and strategies used by the children. Unlike dree-form or creative expression tasks, the drawings in our study have to fulfill a functional goal: to document and communicate, to convey knowledge about the physical artefact previously constructed. As such, they ought to be informative about the essential features of the constructions. For example, the use of canonical or prototypical schemes is no longer relevant for describing the necessary features and details (structural, mechanical) of a working artefact. Hence, the importance of the resources used to represent these features, e.g., selection of appropriate views, of foci, of ways to unveil key features (even if these are hidden or not visible from the chosen view). In engineering drawings, these resources are praised as essential for advancing the design, planning, and actual construction of artefacts. For example, exploded views, showing numerous levels of "insides", or multiple projections of an artefact in the same drawing space, are consider legitimate resources in engineering processes (Ferguson, 1994). From this perspective, children's "violations" of supposedly perceptually correct rules, might be considered as their representational solution for producing a sound description of the construction.

Concluding remarks

A vast body of knowledge about young children's drawing has been produced for more than a century of research (e.g., Luquet, 1927; Piaget & Inhelder, 1971; Arnheim, 1997; Wilats, 2005). This impressive body of knowledge embraces many essential aspects, such as developmental paths, characterization of visuo-motor processes, detailed account of the drawings' features or of skills and strategies involved in drawing. However, most theoretical and research work focused on children's free, intuitive and/or spontaneous drawing. And most data collection focused on children drawings of given objects, even their copy of drawings of objects, or on free representation of ideas or feelings.

In this study, we addressed two aspects that differ from the foci of previous work: (a) children draw what they have constructed; and (b) the drawing has a functional purpose (i.e., documentation) as part of a design task. We examined drawings within the context of a pedagogical approach that expands the experience of assembly and construction play in kindergarten and includes drawing for documentation and reflection purposes.

We are aware that this is only a preliminary study. Further studies are needed to broaden our understanding of this complex topic and to shed light into how this engineering-related drawing process contribute to the development of children's representational abilities in design tasks.

Further studies should focus on additional functional purposes within design processes, e.g., sketching for exploring ideas or elaborating on these with peers, drawing for planning a design, or for prescribing the actual construction of an object.

Additional research should also focus on children's drawing in more structured design tasks, were explicit requirements and constraints are part of the process.

Last but not least, an important venue of research should focus on the effect of functional drawing on the development of cognitive processes and skills linked to academic readiness for formal schooling.

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Are my technology lessons for girls? The Gender Sensitive Education Checklist (GSEC) for teaching Science and Technology.

Eva Dierickxa, AP University of Applied Sciences and Arts, Belgium
Kato Luyckx, AP University of Applied Sciences and Arts, Belgium
Jan Ardies, AP University of Applied Sciences and Arts, Belgium

Abstract
In times of shortages in STEM professions, the untapped potential of girls with a STEM talent is a waste on a personal, social and economic level. Childhood is believed to be a very important formative stage in which children develop an early interest in specific occupations and teachers can have an important influence by developing lessons in such a way that girls are getting motivated for technology and/or science. This paper describes an educational design research study, in which we developed a checklist for teachers to screen the gender sensitivity of their STEM lessons and materials. The checklist contains 20 different questions categorised in four main pillars, namely: the fundamental critical attitude, the image of technology, guidance & interactions and didactical methods. Overall, the Gender-Sensitive Education Checklist (GSEC) can be used to tick what is already going well, ensure these roots can anchor strongly and focus on what teachers can do next to act in a more gender sensitive way. Preliminary evaluative findings suggest that the GSEC could potentially be an inspiring tool for teachers to continuously rethink their STEM lessons and materials. Further research is needed to test the effectiveness of the GSEC.

Keyword
Teaching, Gender-sensitivity, Girls, STEM, Checklist, equity

Introduction

> *"But that's not for girls, is it!?" Sam (8y) shouts as he pushes Dunia aside to operate the drone.*

Two problems at the base

Although girls are equally talented in STEM (science, technology, engineering, mathematics), they are noticeably less likely than boys to choose a field of study in which (one of the components of) STEM is a cornerstone (e.g. Blickenstaff, 2005; Ceci & Williams, 2010; Eddy & Brownell, 2016). By the age of twelve, girls show less positive attitudes towards a future in STEM than boys (Denessen, et al., 2015). This untapped potential talent is a waste on a personal, social and economic level (van den Hurk et al., 2019). It is unfortunate that children choose a course of study based on gender expectations and/or norms instead of skills, ambition and personal preferences. The consequences of these imposed choices is that a lot of female and diverse talent is missed. Certainly, in times of shortages in STEM professions, a society cannot afford to neglect professional talent, while a more gender balanced playing field will undoubtedly also lead to a more personal fulfilment on the girls' behalf.

Childhood (age 6 to 12) is believed to be a very important formative stage in which children develop an early interest in specific occupations and in which they increasingly differentiate between occupations and activities they like or dislike (Gottfredson, 1981, 2005). For example, a study by Trice and McClellan (1993) found that as many as a quarter of adults aged 40-55 years surveyed recalled deciding to pursue their current profession as a child.

With this information in mind, another problem arises. Although overt practices of discrimination may no longer be as prevalent as they were in the past, covert and more subtle, often unintentional forms of gender bias and sexism still exist and occur throughout life undoubtedly shaping male/female career choices (Wang & Degol, 2016; So et al, 2020; Ardies et al, 2021). Teachers often work from a so called 'gender-blind' position, meaning they believe they do not take students' gender into account when teaching (Garrahy, 2001). Yet, we know that implicit biases not only shape our thoughts, but also the way teachers set expectations, teach and evaluate their students (Newall et al, 2018; Consuegra, et al., 2016). Teachers must become aware of these implicit biases and ideas, as they do influence their interactions with students. In a study by Newall and colleagues (2018), teachers in a blind test, for example rated 8-year-old girls less academically capable than 8-year-old boys in physical sciences. The adults overall believed that girls were less interested in science and were less likely to enjoy it. This echoes earlier findings from Tiedemann (2000), who found that teachers believe girls benefited less from extra effort in mathematics and believe that mathematics is more difficult for girls than for boys. Such pre-formed beliefs (or biases) about children's abilities and interests are not innocent but have important implications for education. For example, teachers can give less scientific information if they think they are teaching a girl (Newall et al., 2018). Or if teachers believe, implicitly or not that girls have lower ambitions for STEM-oriented education, they can encourage them less, make girls feel that they do not belong or that they are not competent. (Eddy & Brownell, 2016; Wang & Degol, 2013). Furthermore, research shows that the more a teacher believes in the stereotype that mathematics is a male domain, the more strongly their students start to believe this stereotype (Eccles & Wigfield, 2002, Keller, 2010). We have no reason to believe that this would be any different for the education of technology.
Although teachers have a great influence in confirming gender biases and stereotypes, they also have the potential to be important agents in tackling these ideas (Gunderson, et al., 2012).

Our long-term goal therefore is to support teachers in developing lessons and workshops for pupils in such a way that girls are motivated to deliberately choose to continue to follow in a field of study where technology and/or science occupy a prominent place. Therefore, we wanted to develop a checklist that can help teachers to be aware of their gender-sensitive attitudes and behaviour and how to change their behaviour in favour of more equity in technology and science education.

Methodology

Designing a tool for teachers: educational design research as a means for supporting gender sensitivity in the classroom.

Educational design research (EDR), evolved from design-based research, is an iterative approach to designing, implementing, evaluating, and improving educational interventions (Marej, 2021; McKenney and Reeves, 2018). EDR is both a pragmatic and supportive research design for small teaching and learning projects that can inform and make a difference to both students and staff, and subsequently qualitatively evaluates the change (Jetnikoff, 2015). This methodological approach utilizes collaborative partnerships between researchers and practitioners and mixed methods in the design of programs, curricula, and interventions in real-life contexts like the classroom (Barab and Kirshner, 2001). Educational design research has proved to be an effective approach for research projects focused on the design and evaluation processes of instructor training programs and initiatives (Dede et al, 2009).

The study described in this paper utilizes the EDR model (fig.1) of McKenney and Reeves (2018) to develop a practical tool with the means of creating or deepening gender sensitivity among technology teachers to achieve gender equity in the study choices of their pupils.

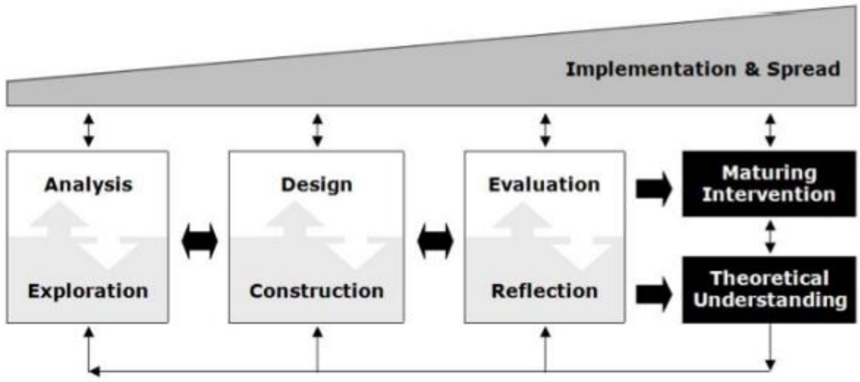

Figure 1: Generic model for conducting educational design research.

In every phase we focused on interventions and strategies that benefit all students and do not exclude anyone (male, female, non-binary). For example, we did not include interventions in the checklist that have a positive influence on the participation of girls at the expense of boys. After all, we advocate for messages and activities that clarify that the STEM field is diverse, inclusive and can present an intellectual challenge for a wide range of people (Diekman et al., 2018).

The **first phase (analysis and exploration)** consisted of a thorough literature review on both explicit and implicit barriers that girls and women experience when (not) choosing for a study or career in technology and proven opportunities to overcome these barriers. We also looked at and screened existing supporting materials, such as checklists or toolkits to support gender-sensitive teaching, such as the checklist of the institute of physics (2019) and the guide for gender sensitive learning materials (Van Tieghem, s.d.). This resulted in the main principles and the overall structure of the checklist.

In addition to literature research, we gained insight into current challenges and good practices regarding gender-sensitive STEM workshops in the Flemish context through both surveys and desk research. During the desk research, we took a critical and constructive look at existing lesson plans from the Technology and Science Academy, which is an organization that provides science and technology workshops for children from the age of 6 to 16. We took a multi-stakeholder perspective by investigating, in collaboration with Finnish and Belgian experts and teachers, how we can (re)design existing technology lessons and workshops to attract girls. Subsequently, the focus was deepened on technology workshops for students aged 10 and up.

In **the second phase (design and construction)**, we developed a first version of the checklist based on insights from the previous phase. We translated the big ideas from the in-depth literature research of the first phase to key points and questions on which teachers could score themselves. This was carried out by the researchers and double-checked by experts.

In support of this checklist, we also developed an introductory workshop for teachers to provide more profound and sustainable support to use the checklist. The development of this workshop started from the work of Merchie et al. (2016) to assure ourselves of effective elements, such as a context-bound approach and attention to reflection and practice in practice. Inspired by Van Thienen (2013), in our workshop, we made use of appreciative inquiry. In this strengths-based approach to individual and organizational change, participants arrive at concrete and individual plans and steps, based on a description and reflection of reality (one's current workshop or teaching practice) and by projecting a dreamed future (gender-sensitive STEM activities).

During and after the design phase, we went through **the third phase** of **evaluation and reflection**, with a strong focus on implementation in practice. First, we followed several evaluation cycles by conducting walk-throughs of the design with both the Finnish and the Belgian partners. Second, we ran three small pilots of the introductory workshop, once with four student-teachers who voluntary organised and guided extracurricular STEM-activities for young pupils, once with three students who design STEM activities in the context of their bachelor theses, and once with seven STEM-teachers from a secondary school. Based on their feedback, we finalized the first version of the workshop and the checklist.

Three weeks after the initial workshops, we observed a STEM-activity organised and guided by these participating students to see what did or did not seem to 'stick'. We held a follow up focus group with these students about the perceived effect of and feedback on the workshop and checklist. We conducted a similar in-depth focus conversation with the other participating student-teachers, four weeks after attending the workshop. In these interviews and focus groups the focus was on the experience and efficacy.

Subsequently, we focused on a broad implementation in the educational field and organized three workshops that were promoted through the most popular Flemish teachers magazine (Klasse.be) and newsletters of the partner organisations. Participating was free. During this phase, we refined the workshop and checklist based upon various feedback rounds. Participants in the offered workshops were 58 teachers, teacher-students, counsellors, teacher educators, and technology-experts. After each workshop, the participants were asked to give feedback through a survey about the content, organization and user-friendliness of both the workshop and the checklist, to redesign and optimize the workshop and checklist. This survey consisted of both questions based on a Likert scale as well as open-ended questions.

As a result of the feedback, we added more concrete examples to the workshop and created opportunities to look at our learning materials and teaching behaviour. In addition, we made the introductory workshop longer in duration so that we could discuss those aspects more extensively during the workshop.

Matters that have been adjusted throughout these various cycles, include:

- Using clear language in the statements,
- Eliminating double negative statements,
- Adding a few statements, partly based on other research or other instruments
- Dividing the checklist into one concise and one comprehensive format,
- Add a short guide and mark "yes" and "no" instead of "true" or "wrong" with each statement
- Adding real-life examples and cases

Although we cannot generalize the results due to the limited size of the study, they served their purpose in the study design. After all, participants indicated that they *felt* more aware of the gender-sensitive supervision of STEM activities by using the checklist and after following the workshop, by making sure that they portray women in their teaching materials, pay attention to language use, and so on. Further thorough, systematic evaluation and analysis is needed to follow up on the effectiveness of the GSEC-tool in the field.

Based upon their feedback, this educational design research resulted in a checklist and accompanying workshop which will be described below.

Content of the checklist and workshop: four main principles

The thematic literature review in phase 1 was summarized in four main pillars, that in our opinion, include all the practical and empirically based suggestions.

The starting point is always the teachers' self-reflection to map out their strengths, mindset, and blind spots around gender-sensitive teaching. In this way, we develop a checklist that starts from a solid basis or ground condition, namely self-reflection by the teacher or counsellor about the implicit ideas and (general existing) prejudices about gender in STEM. On this basis of awareness, we further provide more suggestions based on literature. Because this checklist serves as a reflection tool, teachers can mark on a non-numeric scale the extent to which they believe they agree with a statement or question. In this way, we emphasize the possibility of growth within gender-sensitive teaching, rather than see it as a measurable, quantitative subject.

The developed workshop is constructed based on the four principles of the checklist. Optimal conditions for the workshop seem to be a duration of at least 120 minutes in groups of maximum 20 people to ensure sufficient interaction. The workshop starts with enhancing of the sense of urgency of this topic and presents theoretical insights, coming from previous research and evidence. We alternate these facts and figures with interactive exercises which support the transfer to teachers' own practices, such as a screening of their own learning materials in view of gender representation. Ideally, this workshop is given in real life, to optimise the chances for interaction and watch non-verbal cues from participants. Furthermore, the participants are actively engaged in reflection by immediately using the GSEC and thereby linking new insights to own ideas and classroom practices.

Fundamental critical attitude

Since knowledge and awareness of existing interaction patterns with students is the first step in changing and improving the interaction, a gender-aware basic attitude is indispensable. Teachers needs to be aware of the possible influences of gender (Consuegra et al., 2013) before we can take further steps in the design process of a gender-aware technology lesson that gives girls equal opportunities. Canning et al. (2019) argue for example that beliefs of the instructor about the nature of intelligence can likely shape the way they structure their course, their communication with students, and the encouragement or discouragement of students' persistence.

We, therefore, invite teachers to critically and honestly reflect on their ideas and bias to actively work towards truly inclusive technology and science lessons.

Within this dimension, we offer teachers two reflective questions:

1. Are you aware of the implicit ideas and prevailing prejudices about m/f/x in society? (example: boys are better at engineering than girls)
2. Are you aware of your own ideas and beliefs about m/f/x? (for example: to girls, I need to give feedback more sensitively.)

The image of technology

Children form an early picture of what a scientist or engineer should look like. If they do not recognize themselves in this, their motivation to continue with this study or career choice decreases (Blickenstaff, 2005). Role models are therefore important in arousing girls' interest in technical careers. The use of female role models may increase an important sense of belonging in STEM (Blickenstaff, 2005). The most effective role models are those with similar backgrounds to those of the participants. That resemblance can encourage girls to imagine that one day they might end up in those positions (Martens et al, 2006; Zirkel, 2002).

It is also important for boys to see counterstereotype examples. Children need to see and hear that you do not have to be a 'geek' or an outsider to choose such a direction. Regularly bringing female and stereotyped successful role models into the classroom has a positive influence on the attitudes of girls and boys towards women in technology and ICT (Shin et al., 2016; McGuire et al., 2021). People need not one but several mutually reinforcing examples to see counterstereotypes as evidence of trends (Eagly and Woods 2012; Richards & Hewstone, 2001). Hence, it is crucial that a teacher would not "check off" the diversity box when a female engineer once testifies about her work experience. That box can only be checked when the manuals and work materials for the whole year are being critically screened. Contrary to what we might think recent research shows that much of the learning material and imagery used in STEM classes still confirm the stereotypical idea that science associates with white men (Kerkhoven et al., 2016; McGuire et al., 2021).

One teacher we observed for the project told us that he had added pink paint and glitter to his technology projects to attract and stimulate girls in "their talents". This is described in the literature as 'pinkwashing' (Myers, et al., 2019). Contrary to what this teacher thought, the addition of glitter and pastels does not provide more motivation for technology education. On the contrary, they can reinforce girls in the idea that this is not for them by giving extra attention to their gender, which is associated with negative stereotypes about STEM (Heybach & Pickup, 2017). This may lead to reduced performance through stereotype threat (Steele, 1997; Spencer, et al., 1999). In other studies, the addition of pastel-colored blocks in a game also did not positively affect girls' technical ability but negatively impacted boys' performance (Mulvey et al., 2017).

When designing a gender-sensitive lesson, teachers should consider the image they create in the classroom. After critical self-reflection (pillar one), they should screen teaching materials, videos, posters, and stories: As part of the critical self-reflection (pillar one), they should screen teaching materials, videos, posters and stories using the questions in the checklist below.

In the developed checklist and accompanying workshop, we direct teachers towards online and offline intersectional gender sensitive imagery of science and technology on websites, picture books, biographies, etc. (e.g. the book on Girls and Science by Rachel Ignotofsky, 2016)

Within this dimension, we offer teachers five reflective questions:

1. Is there an equal number of men and women presented in your learning materials?
2. Do the women in pictures play an active role? (For example: plumber Burçu is pictured repairing the faucet)
3. Do you pay attention to the (historical) contribution of female scientists and technicians? (e.g. Edith Clarke, Grace Hopper, Hedy Lamarr, Katherine Johnson, Annie Easley,…)
4. Are the children brought into contact with a female supervisor, scientist, or technician during class or workshop?
5. Do you use neutral-colored material? (Avoid offering pink or purple hammers or work trays to 'attract girls')

Guidance and interaction in the lessons

Our interaction with children potentially has a major influence on, among other things, the self-image of girls and whether they feel like they belong in STEM disciplines. Children actively look for cues about gender in their environment to organize and make sense of their social world (Ruble et al., 2006). Among other things, children seem to use hints in language like occupational titles to categorize occupations along gender lines. In most European languages there is a distinction between the male and female form of scientist for example. The current practice of using the generic masculine form as a so called 'neutral job title' when describing stereotypical male occupations may therefore contribute to the preservation of gender-stereotyped images in adults and children (Vervecken et al., 2013, 2015). This advice can also be relevant in English when repeatedly, and often subconsciously using 'he' rather than 'she' for a technician or scientist.

It seems that when both the male and female professional titles are being used in pair-form, boys and girls feel equally addressed, this boosted children's self-efficacy regarding traditionally male occupations and increased the interest of girls in stereotypical male professions (Vervecken et al., 2013, 2015). Both boys and girls also believe more strongly that women can also be successful in these professions. The use of pairing in job titles supports women to envision more successful peers (other women) thereby also increasing their interest in STEM careers (Vervecken et al., 2013, 2015).

Other research shows that naming science as behaviour or action ('we are going to do science'/'you can work well independently') rather than as a fixed identity ('we are scientists'/'you are independent') contributes to the interest of young girls (4 to 9 years old) in technology. These effects are especially true for children who are targeted by stereotypes that suggest that they may not be the kind of person who is successful in STEM, in this case, girls (Rhodes et al., 2019).

Many girls and those around them think that for technology or science you need to have an innate and fixed talent (Hill et al., 2010, Ardies et al, 2015a). Therefore, it is important for teachers to give students explicit appreciation for their learning process, approach, commitment, and creativity. Teacher should clarify that everyone can develop and improve STEM skills through practice. Providing feedback and language that is growth-oriented and not just about the result can help. Teachers also need to correct misbeliefs and myths like these and clarify the skills in the workshop are not 'innate' but can improve with practice (Wang & Degol, 2016).

Boys are more likely to overestimate their qualities while girls are more likely to underestimate themselves, especially for science and technology subjects (Correll, 2001; Nagy et al., 2010). Van der Heyden et al., 2016). Extensive research confirms that for example low math self-efficacy plays a major role in girls' or women's underachievement in math (Durik et al., 2006). In other words, girls who estimate themselves lower will also perform lower in mathematics as a result. This self-assessment is important because both girls and boys who rate their mathematical competence highly are more likely to enrol in a mathematical field and start a STEM career (Dweck, 2007).

Fortunately, teachers can make a difference. After all, teacher expectations can influence students' self-esteem and performance (Metheny et al., 2008). Teacher expectations differ for individual students and are related to differences in treatment and performance (Hattie, 2009; Jussim & Harber, 2005; Turner & Patrick, 2004). Indeed, girls are more likely than boys to be disadvantaged by teachers' low expectations of math achievement (McKown & Weinstein, 2002; Wang, 2012). This is very closely related and stems from the basic attitude we discussed in pillar one.

It follows that teachers often tend to ask girls less direct and open questions and to give them fewer compliments (Becker, 1981). Teachers should deliberately oppose this and try to critically examine their own interactions.

Within this dimension, we offer teachers seven questions:

1. Do you use the masculine and feminine form (or he/she...) for professions, if possible, in your native language?
2. Do you use active language? (For example, ‘we are going to design mini-robots’, instead of ‘we are going to be technicians’)
3. Do you use growth-oriented feedback? (For example: ‘I admire your perseverance, even if it doesn't work right away. Are there any other ways?’)
4. Do you address students on gender stereotypes statements? (For example: compliment girls on being strong and good in maths and boys in being caring)
5. Do you limit gender-oriented tasks? (For example: avoid asking the girls to clean the tables and asking the boys to replace the tables and chairs)

6. Do you actively monitor student turns? (Do you make sure that a (male) student is not dominating in an activity or lesson? Do you wait long enough after asking a question for all (m/f/x) equally?)
7. Do you ask all students the same type of questions?

Didactical methods

Girls generally seem to prefer a contextualized curriculum, in which technology is seen as a means to solve social problems or to enrich human experiences (Ardies et al, 2015a). In other words, it's important to clarify the social, human relevance of your technology or science activity or place the assignment in a broader context where teachers clarify its relevance. "We are now programming robots, which can also be used to provide companionship to lonely people", for example. Or "design a solution in your group for the plastic waste in the local stream". Or "with such a formula you build a solid bridge that gives people from the village the chance to get their food on the other side".

Hands-on activities in which children actively get to work have a positive effect on the motivation of boys and not negatively for girls and we would therefore generally recommend it. Girls feel even more motivated if they can design and conduct their research (Ardies et al., 2015b). There are rich opportunities in formulating a research question, devising a solution route, making mistakes, and formulating an answer. Making a connection between students' life and STEM lessons can also increase interest and outcomes, especially for students with low success expectations (Hulleman & Harackiewicz, 2009).

Many extra and after-school activities offer experiential learning with problem-solving, creativity, and design skills, and offer research opportunities in scientific areas that are often not part of the regular school day. These extracurricular activities have the potential to play an integral role in creating interest in STEM fields and careers.

In their study of after-school activities, Anderson and Gilbride (2003) found that participation in a STEM-focused program can significantly increase girls' interest in pursuing engineering as a career. Therefore, there are rich opportunities in such workshops and refresher courses for students to achieve equal opportunities. We, therefore, work closely with these organizations to convert the screening tool into gender-aware STEM workshops.

Within this dimension, we offer teachers six questions:

1. Do you promote collaboration in the classroom as well as competition?
2. Do you divide groups based on characteristics other than gender? (For example: not 'boys against the girls' but 'red and blue shirts against the others'?)
3. Do you place the activity in a broader context to clarify the relevance? (Are you starting from an authentic problem or a real question, like 'how can we display all the drawings from the children in such a way all parents can see them?')
4. Are you clarifying the social, human relevance of STEM in your activities? (For example: 'In the future, these robots will be able to offer the elderly company' or 'drones will also be used to clean the oceans')

5. Do you give enough space to experiment and get started with problem-solving? (For example: the students do not always have to follow a step-by-step plan for every activity)
6. Do you let the students design and carry out research based on their own choice?

Discussion and conclusion

This research and the developed tool started from the teacher's role in promoting girls' interest in STEM activities. Of course, the dropout of girls in STEM courses and careers is not a direct result of what the teacher alone is doing (Çınar, 2022). For example, stereotypes about gender and STEM affect not only teachers and tutors, but also the student and her/his friends, family and future employers (Kelly, 2016). Cultural and social beliefs, policies, and economic and work-related developments also, directly and indirectly, influence student behaviour. A teacher can only do so much. Nevertheless, teachers and their wider school team must take responsibility for this and do everything possible so that students can make a choice of study that starts from genuine interests and talents and is not based on what the student thinks is expected of her/him/them, based on gender, for example.

To support teachers in organizing gender-sensitive STEM activities and interactions, we developed a checklist and accompanying workshop. This checklist may seem like a collection of many trivial pointers, or maybe it all might seem obvious to many. Yet, as we have read throughout our thematic literature review, the road to gender equity in STEM and the broader society is not paved on big projects, grand gestures or expensive professional development. It is the small changes in our everyday language, the implicit and unintentional biased expectations and textbooks we use in our classes that will need to make the change for a more gender equitable society. When teachers start reflecting on societal and personal ideas about gender and how these affect their class activities, teachers are taking very important steps in the direction of gender-sensitive education. The Gender-Sensitive Education Checklist (GSEC) can be used to tick what is already going well and ensure these roots can anchor strongly. Next, teachers can pick a few points for improvement that they want to work on first. It is not necessary nor possible to give equal attention to all four principles at the same time. By reaching out to teachers and give bite-sized evidence-based advice and questions in our checklist, we aim to bridge the gap between research and teaching.

However, the evaluation phase presented in this paper is limited in terms of effectivity. As expected withing an EDR-study, our research focused more on participants' experience with the GSEC, with the aim of refining and improving the tool, rather than studying the effectivity of the tool itself. Further research might focus on the learning gains and effectivity of the tool and accompanying workshop on teachers' gender sensitivity. Thereby, future studies can focus on the impact on students' ideas of gender.

We are convinced that all teachers can make a difference for their students. With that in mind, the GSEC provides teachers and teacher-students with a robust tool to support gender sensitive teaching, that is grounded in both literature and user experience. By summarizing practical suggestions from recent research in a practical tool and workshop for teachers, we hope to be able to support teachers in working on a gender-sensitive technology or science lesson. Such lessons ultimately ensure that all children feel motivated and addressed and can make a truly free study and career choice, regardless of their gender.

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From a teacher student's view – how STEM-actors have impact on teacher education and teaching in STEM

Susanne Engström, KTH Royal Institute of Technology, Sweden

Abstract
In this study, Swedish STEM-teacher students' experiences of STEM-actors are explored. 85 teacher students have visited each, of a total of 21 different STEM-actors (science centres, museums, maker spaces, code clubs etc.) who all offer school classes STEM-activities but also in-service teacher education. The teacher students were given the task of observing, interviewing and analysing. The teacher students' report texts constitute data that has been analysed thematically. In the teacher students' statements, no disputing attitude towards the STEM-actors emerge. It seems that a preconceived approach is being developed among the teacher students that the school system needs external STEM-actors for both further education and teaching in T&S. The student teachers become convinced that the formal school setting fails to make the subject of technology fun and interesting enough. Nevertheless, the student teachers are not completely convinced that doing (construction), i.e. practical work, is always what should be most important. They express the view that the teaching must contain engaging, fun and interesting elements and that it requires subject competence of the teacher. The student teachers are undergoing a teacher training course which includes encounters with STEM actors, that seem to have resulted in a view that technology teaching in a formal school setting is insufficiently interesting, engaging and fun.

Key words
STEM actors, science centres, technology teachers training, student teacher training

Introduction
In Sweden, formal education in the school system is conducted in collaboration with actors from outside the formal school system (out-of-school science environments). Science centres, different museums and other actors (e.g. various actors in programming, maker spaces etc.), referred to here as STEM actors, offer their services to actively employed teachers, both for the teachers' own continuing education and to receive school students and provide teaching in school subjects. This is not unique to Sweden. It occurs in many other countries, and researchers throughout the world have studied the similarities and differences between learning in formal and informal contexts. Some of the research has been focused on contexts, affective and social aspects, the nature of participation and the specific content (Martin, 2004; Stocklmayer, Rennie, & Gilbert, 2010; Wellington, 1990). STEM actors also collaborate with the universities' teacher training programmes by offering teaching facilities, equipment and teacher-led teaching for students who are to become preschool teachers and teachers in various subjects, such as science, mathematics and technology. Collaboration with different actors outside the school is particularly prevalent in the STEM subjects, and it has been shown to result in fruitful learning opportunities for student teachers (Avraamidou, 2014; McGinnis et al., 2012).

The reason that STEM subjects, school students, teachers and student teachers receive this attention from different actors outside the school is that school students' interest in STEM subjects is considered too low, and that stimulating teaching activities are needed which schools in the formal school system do not seem capable of providing (Adams & Gupta, 2017). The STEM actors' starting point is that they are willing and able to contribute to increased interest in STEM among children and young people. They base their activities on their own great commitment and believe that this, together with their environments and activities, leads to increased interest in learning among students of school age (Martin et al., 2016).

The teaching approach of many of the STEM actors is based largely on Dewey's ideas of "learning by doing". Sometimes the learning in question is described as multimodal, which means an environment rich in materials, models and experiments behind which phenomena and principles are concealed, which creates interest and allows for its own investigation (Rennie, 2014). At many of the STEM actors, there are also links inter alia to makerspace. This is the concept of an environment that focuses on learning rather than primarily teaching and which gives participants an opportunity to engage in a process-oriented, authentic task based on the individual's interest and commitment (Halverson & Sheridan, 2014). The maker movement originated in *the do-it-yourself movement* and gives participants access to technology, tools and materials that previously only existed for various professions (ibid.). Many STEM actors describe their operation as an environment with adaptable and practical tools that support and cultivate school students' interest in science and technology. Often, the intention of STEM actors is to interconnect formal and non-formal education, they want to address society as a whole, span multiple subject disciplines and support multiple ways of knowing and learning (Zolotonosa & Hurley, 2021).

The intention of STEM actors is thus to educate and inspire student teachers and active teachers, as well as children and school students. In addition, many of the STEM actors offer activities for children and young people during their free time, on weekends and evenings, as well as during holidays. They may also put on longer courses during holidays and at weekends. In some cases, leisure activities can involve costs for the individual child.

Evaluations and studies show that STEM actors are considered to be an untapped and important resource for active and prospective teachers (Melber & Cox-Petersen, 2005; Carvalho, 2021). Studies show inter alia that STEM actors can be of great help to both teachers and school students in teaching/learning situations when they create a wealth of both cognitive and affective activities, linked to the school students' previous experiences (Mujtaba et al., 2018).

In terms of the collaboration of science centres and other STEM actors with the school, the studies focus on the learning environment offered and its effects, in particular, the effect that the environments have on students' interest in STEM. Studies show that the actors' environments clearly present STEM as something that is fun and interesting, in which everyone can immerse themselves and find their future profession. School students feel they become motivated to learn through the activities offered by STEM actors (Lavie Alon & Tal, 2015; Bamberger & Tal, 2007). The STEM actors offer well-equipped and exciting premises, and this has also been shown to contribute to increased interest (Adams & Gupta, 2017).

At the same time, studies show that STEM actors can be very focused on visitors' feelings, interest and attitude, with the aim of increasing their self-confidence in STEM, but are significantly less focused on teaching within the subjects (Sasson, 2014).

STEM actors have a desire to reach all students; they want to act in such a way that everyone will thrive and understand what is being taught. However, research shows that the actors' intention to reach everyone could be interpreted as contributing to expectations of students that are far too low (Shaby et al., 2018). In addition, studies show that the actors' environments tend to attract certain groups and that other groups do not feel as welcome. Leisure-time visits to the environments are mostly the preserve of children and young people with well-educated parents, which means that these groups also feel at home in the environments when they visit them with their school classes (Godec, S., et al., 2022). Similarly, children and young people with highly educated parents are more likely to feel at home in the environments that are constructed on the actors' premises, such as laboratories and robotic labs. Many children of highly educated parents have heard their parents talk about similar environments, or indeed the parents have even shown them to their children. Children who lack such references may find laboratory environments to be very alien. Studies also show how the STEM actors' way of presenting their environments can also contribute to a sense of alienation in some children and young people (ibid).

STEM actors have been criticised for conducting activities that misrepresent research in science and technology, that focus on principles and phenomena rather than processes, and that take science and technology out of context without looking at inherent problems (Bradburne, 1998; Davidsson & Jakobsson, 2007). The actors have also risked being accused of presenting a normative picture of STEM, which has led to internal development and transformation projects. The purpose of the actors' development projects has been to change both the image of the actors' environments and the traditional image of STEM (the "crazy" scientist, "computer geek" etc.). In recent years, therefore, some actors have changed their way of working and their environments (Lawrence & Tinkler, 2015.). STEM actors have inter alia collaborated globally to jointly develop their operations and make themselves accessible to more target groups. They want to be an active player in teacher education and the continuing education of teachers. In particular, they highlight the aim of creating pathways to welcome school students of all backgrounds to science and technology learning and to meet them wherever they are (Zolotonosa & Hurley, 2021).

Purpose of this study and its central question

Against this background, a study has been conducted of the experiences, as related by student teachers, of various STEM actors, after the students visited the environment and interviewed educators. The aim is to investigate the impressions, experiences and perceptions aspiring teachers obtain from the encounter with STEM actors within the framework of a teacher training course. These are impressions that may colour the future role of the teacher.

The central question is the following: what emerges from student teachers' reflections about the encounter with a STEM actor?

Methods

To find an answer to the question, a case study has been conducted. A total of 85 student teachers each visited a total of 21 different actors (science centres, technology museums, open-air museums and similar actors), all of which offer leisure activities to children and young people, as well as activities related to school subjects within STEM to school classes. All actors also offer active teachers continuing education and are engaged in different ways in various teacher training courses.

The various STEM actors are spread across Sweden. The student teachers in the study are all training as subject teachers in technology, mathematics, physics or chemistry, many of them intending to teach more than one subject. Therefore, they intend to become teachers in lower secondary schools or upper secondary schools.

This specific element in their teacher training, the encounter with the STEM actor, together with the associated processing, takes up one week. Prior to the encounter with the STEM actor, the student teachers were invited to first read the following article, as a mandatory activity:

> *Eva Davisson & Anders Jacobsson (2007) Different Images of Science at Nordic Science Centers, International Journal of Science Education, 29:10, 1229-1244.*

The students' task was to observe, interview, analyse and write reflections over a total of four days and then write up an account on the fifth day. The student teachers were to participate in the operation and observe (participate in) the teaching on the first day, conduct interviews with educators and participants and compile these on the second day, study websites and other materials and analyse everything on the third day. On the fourth day, the students had time to compile all their material, conduct supplementary interviews and prepare their presentation. After that, the student teachers were to present their conclusions. Before they started with the task, the students were clearly instructed to read the article, prepare interview questions, observe, ask questions about and analyse the following:

- Who are the participants/school students? (Background, aims, gender/age etc.)
- How is the teaching/session structured?
- What learning objectives and activities are evident?
- What do the organisers want to highlight: subject knowledge, subject culture, ideals, values, gender aspects, etc.?

The student teachers were then asked to observe and possibly try to teach something themselves, all the while taking notes. The students were encouraged to have plenty of material which they could analyse, present and use to write up their own reflections on everything they had encountered.

The written reflections of the student teachers, their presentation slides and the accompanying scripts constitute the data set for this case study. The parts in which the student teachers presented their analyses and reflections constitute the primary data set, given that the purpose of the study is to gain an insight into the student teachers' impressions and experiences.

The student teachers' analyses, reflections and presentations are thus textual material that has been analysed thematically with the aim of identifying apparently important aspects of what the student teachers want to highlight, based on their main impressions. The thematic analysis has been carried out systematically and inductively, inspired by Braun and Clarke (2008). The data set has been left to speak for itself, the text has been read and re-read before commencing on coding of the text contents. Themes have been generated by the coding and then grouped into summary main themes.

The main themes may be said to answer the central question and give a picture of the impressions emerging from the student teachers' reflections.

Results

The student teachers come away from the encounter with the STEM actors having gained an impression. This is the impression that the student teachers present and reflect on in their texts. The student teachers describe the extent to which they agree with aspects they refer to in respect of the STEM actors. The student teachers emphasise the importance of the actors for schoolchildren and teaching, but also the impressions they have gained regarding the view of the competence of active teachers and the role of the school. The impressions described by the student teachers have been compiled into the following themes.

Build up the school student into someone great

A basic assumption, discernible among the students and which they also ascribe to the STEM actors, seems to be that more individuals are needed who invest in a career in science and technology. They also believe that being well-educated in science and technology is a valuable general competence to possess. The student teachers state that the STEM actors undertake important work and that their operations are needed to help the school student achieve something great. At the STEM actors, important characteristics of human beings are highlighted, as are the kind of knowledge and competences that will be required for the future.

> *"The goal is for everyone to leave their premises a little smarter and that their curiosity is aroused." (Student statement)*

Often, the STEM actors also link valuable knowledge and abilities to sustainable development. According to the student teachers, the STEM actors emphasise many perspectives: how nature nurtures; the need for self-confidence in technology; the need for new innovators; the importance of keeping career paths in mind; the fact that research can be undertaken by ordinary people and that girls should feel that they can choose careers in STEM; the view that curiosity, commitment and creativity are important qualities, etc. These are perspectives that a majority of the student teachers emphasise in their analyses.

> *"The aim is to bring out school students' hidden abilities in science and technology. They want to show school students that science is for everyone. They want to arouse interest and develop subject knowledge in a playful way, connecting science to reality." (Student statement)*

According to the student teachers, the STEM actors want to get young people to explore the world and believe that it is important for them to develop into individuals who base statements on science and who value investigations and experiments. For the student teachers, the STEM actors thereby evince a set of important features characteristic of humanity. The student teachers present what the educators say without directly identifying any inherent problem. For example,

> *"educators believe that boys are more interested in function while girls are more interested in design and decoration". (Student statement)*

In the case of many of the student teachers, the STEM actors' statements are presented as truths. They underline how science and technology are areas that comprise knowledge which is important for the future. Working in these areas requires certain characteristics and viewpoints. For the student teachers, there seems to be nothing problematic about this. They seem to share the same values and viewpoints that they perceive the STEM actors as presenting. Among other things, the view that career paths in science and technology are important, and that this also needs to be emphasised for school students.

> *"The inspiring environment also gives school students a clear picture of possible career paths within STEM. Scientists are also ordinary people. An ordinary person can become a scientist." (Student statement)*

Get school students to understand what is interesting and fun about STEM

The students value the fact that the STEM actors seem to apply great enthusiasm and emphasis in spelling out the importance of stimulating the school students to develop curiosity, creativity and an interest in science and technology. However, the student teachers also construe this as an indication that the school does not manage it to a sufficient extent. The students contrast the way in which the STEM actors talk about the subjects and what is important with the way the subjects are taught in school. The student teachers reflect on and seem to value the crucial importance of the STEM actors in compensating for deficiencies in the school environment. The statements of the student teachers all tend to express the same opinion. In their descriptions, the student teachers emphasise how important it is for school students to become interested and involved. According to the students, this is made possible by the environment and concept of the STEM actors.

> *"It's hard not to get involved in the task when it's so obviously interactive and conducted in a stimulating environment." (Student statement)*

A majority of the student teachers emphasise how the STEM actors take the view that school students should learn that science and technology are fun and exciting. The student teachers value the commitment of the STEM educators and their positive attitude to showing that the subjects are fun. In their presentations, the student teachers imply that it is an accepted truth that such an approach is necessary. Both the STEM actors' presentations of their operations and the student teachers' analyses convey therefore the importance of demonstrating to the school students that science and technology are fun. This can be interpreted to imply that the point of departure for the school students is that science and technology are boring and uninteresting, which is why the prevailing approach is to respond at all costs to this dullness by presenting the subjects as fun and interesting. The student teachers do not reflect critically on this, but evidence an unchallenged belief that students need to find the subjects fun. The student teachers are enthralled by the STEM actors' school programmes which, with a variety of different means, manage to present the subjects in an interesting fashion.

> *"The school programmes are designed with the aim of generating interest in science and technology. In order to arouse interest and understanding among the school students, a lot of props are used, and phenomena are explained based on different models." (Student statement)*

Provide security for insecure teachers

The student teachers are attentive to where STEM actors are coming from and clearly point out that active teachers possess insufficient competence in science and technology. However, the student teachers do not seem to feel as though this applies to them and seem to take the view that many *other* teachers lack the relevant knowledge. The view that many teachers in primary schools lack the necessary qualifications and lack knowledge in science and technology is reinforced among the student teachers by the fact that the STEM actors stress it and highlight the importance of offering continuing education to teachers. Although the student teachers do not believe that they themselves lack subject competence, they express the view that *teachers generally* have insufficient knowledge. This can relate to e.g. programming or chemistry. For the student teachers, the role of the STEM actors as providing teachers with continuing education is important. The impression is formed among the student teachers that active teachers do not really have the knowledge and competences to teach science and technology as these should be taught.

> *"It would be good if the actor could become more integrated into school education, for example, to provide teachers with continuing education." (Student statement)*

The student teachers also convey the STEM actors' position that active technology teachers who have knowledge are nevertheless not always correct in what they do, which is why the STEM actors can help in these situations too.

> *"Here they meet the school students at their level; they have put a lot of work into developing activities at the right level. The educator believes that technology teachers often design activities at levels that are a little too high." (Student statement)*

The STEM actors described their school programmes and their relationship with active teachers and teaching to the student teachers, who value the aims of the programmes. Student teachers emphasise how the school programmes should both relate to the syllabuses and be fun; they should provide opportunities and act as a support for the teacher.

> *"The connection to the school's learning objectives is not always strong, because the lessons should primarily be entertaining. But there is room for teachers to make connections themselves to the syllabus in technology." (Student statement)*

The STEM actors' descriptions of their school programmes and their application seem to reveal a view of how active teachers may view the visits, something that the student teachers take on board.

> *"The teacher gets a programme where the activity is linked to syllabuses; the teacher gets suggestions for preparatory work and follow-up work with the class. The teacher should not see the visit as simply an isolated fun way to pass the time, but as an integral part of technology teaching." (Student statement)*

Didactic foundations

The student teachers note and emphasise that the STEM actors have very well-organised activities: they do not have a lot of time available and follow well-planned arrangements. Admittedly, the STEM actors seem to want to emphasise how important it is to listen to the school students and start from their level, wishes and their experiences, but at the same time the activities are well-planned and prepared. The student teachers describe how the actors have a given plan that they follow; they have prepared materials and resources, and they work efficiently and purposefully. Their efficiency in particular is emphasised by the student teachers.

The student teachers note the didactic foundations expressed by the STEM actors, and the student teachers highlight these positively in their analyses. For example, how important it is for school students to use their entire body in the learning situation.

> *"We believe that the actor is not just a place but a way to educate yourself; you learn best when using your whole body, your mind, your hands, your feet – everything." (Student statement)*

The student teachers note the apparent importance for all STEM actors of doing, something which also seems to win over the student teachers despite some doubts about the lack of theoretical elements.

> *"The main thing was that the participants were active, learning by doing, the school students were not given any ready-made solutions; they had to explore their ideas and thoughts. We gained invaluable didactic insights. We saw how the school students were stimulated in the classroom. But there was a lot of focus on practice and too little on theory." (Student statement)*

The student teachers also state the importance of variety in teaching, as well as the characteristics of a good educator: commitment, passion, spontaneity, experience, insight into human nature and, above all, being secure in their subject knowledge.

> *"They have a set-up with practical elements and theoretical elements, and they get the classes really immersed in the subject area. One of the keys is the educator's commitment and love of their work. They do not have an educational "master plan" that they have elaborated specifically. Rather, they work somewhat spontaneously based on educational ideas, experience and an insight into human nature. However, I feel that it works very well. The idea is that it should be fun to listen. Quick responses. Get into roles. Speak dynamically. You have to be confident in your performance and in your subject knowledge." (Student statement)*

The student teachers describe how they see the STEM actors vary the pace of their presentations and how they skilfully enable visiting school students to discover the content of the subjects. The encounter with the STEM actors and their set-up impresses the student teachers and convinces them of the importance of the actors.

> *"We have been convinced of the positive effects of varying lessons and encouraging exploration by deriving as much help as possible from external actors. The educators*

> *there are competent enthusiasts who have a lot to contribute. They know how to package lessons." (Student statement)*

However, there are student teachers who are also critical to some degree of the STEM actors' didactic approach; specifically, they point out how the focus on practical activities can lack a sound theoretical foundation.

> *"We feel the actor is important in promoting an interest in technology among young people. However, we believe that the actor's teaching can be improved. The interest seems to be less pronounced in older children, and one reason may be that the practical tasks they get to try are often insufficiently rooted in theory. Children understand how an experiment can be performed but not why they get a certain result. A stronger connection to science might contribute to increased interest. Entertainment and theory do not have to be mutually exclusive." (Student statement)*

While the student teachers seem to value the entertainment value of the actors' activities, they also demand a stronger connection with the theoretical basis. In some cases, some student teachers also suspect that there may be shortcomings in the STEM actors' theoretical knowledge.

> *"In the teaching we participated in, we lacked a more comprehensive technical explanation as to why trusses are strong. Some of us who are more versed in strength theory thought that the mastery of concepts was rather lacklustre when explaining what strength and stability mean in a truss structure." (Student statement)*

Fantastic environments

It is not only the educators at the actors who impress the student teachers, but also the environments and equipment offered.

> *"Same content as school but... better equipment, better premises, more inspiring environment" (Student statement)*

> *"The actor is a fantastic resource for mainstream schools because the educator is committed and knowledgeable. The operation is characterised by high quality, great insight and strong commitment; there are lavish materials and expensive equipment." (Student statement)*

The student teachers describe how important it will be for school students to be able to encounter the STEM actors' environments. This is so they can see how different the environments are from their school classrooms where there is a lack of equipment. The STEM actors emphasise to the student teachers that they follow the school curriculum. They say that they have also created activities that can be directly linked to the syllabuses, but that they allow the school students to encounter the subject content in much more inspiring environments, with more advanced equipment, or environments and objects that are distinctive in other ways, with more lavish materials and resources. The STEM actors seem to think that their operations are a necessary complement to the school's teaching which can be implemented in a school setting, but that at the same time it is not a requirement. The student teachers describe the

STEM actors as a valuable complement to the school's teaching that does not even require commitment from the teacher.

> *"The activities are complementary to mainstream teaching, but they have modern equipment. They recommend that the teacher does some form of preparatory and follow-up work; however, it is not a requirement. Some teachers want to tick off central content, while others just think it's nice to get away."*

The student teachers also state that the STEM actors have the resources to create specifically creative, inclusive environments with the aim of attracting all school students regardless of background.

> *"The environment is inclusive; everyone regardless of background or scientific knowledge should feel at home. The important thing is not to know, but to start observing and putting into words what you see. The premises should feel pleasant and homely so that the visitor will feel comfortable and not be anxious." (Student statement)*

According to the student teachers, the attractiveness of the environments comes down to the light, colours and objects that together provide opportunities for interaction and a full sensory experience. The environments provide a high degree of multimodality. Many student teachers describe the environments as being crucial to the students becoming interested in the subjects. However, there are student teachers who point out that the STEM actor in some cases goes too far when it comes to images, sounds, colours, different materials, etc., and that school students may risk being "overstimulated".

> *"The building material consists of a predominance of colourful paper and glitter. There is also a trend towards requiring that something be happening all the time, that all senses should be stimulated at once. There is a plethora of instructions, but it seems to work well anyway." (Student statement)*

The specific technology content

The student teachers also state which specific subject content related to technology teaching is highlighted by the STEM actors. When it comes to technology teaching (which has been chosen as the focal point for this survey), the student teachers' descriptions make clear what appears to be relevant content. The basis for relevance can largely be interpreted in what the STEM actors consider to be important knowledge and relevant abilities, but also things which, in their view, active teachers fail to do because they lack sufficient knowledge or equipment. In the student teachers' reflections after encounters with different STEM actors, a number of themes emerge that recur at several different actors. The student teachers relate that, overall, the STEM actors' technology activities include the following content.

Pneumatics linked to mechanical elements

A number of actors told the student teachers how they allow school students to work on small projects in which they get to encounter pneumatics in combination with mechanical elements in their own constructions. For example, the school students may build a so-called pop-up figure that is controlled by pneumatics, or they may, using pneumatics, move a structure of their own design. Such projects are mainly aimed at school students in the 7-12 age bracket.

Strength and deflection

According to the student teachers, some actors described how school students get to encounter theories related to trusses and that they get to build trusses with e.g. so-called 4DFrame materials. School students thus seem to be given an opportunity to learn about strength and deflection when given the task of building a bridge, for instance. Such projects can be aimed at school students in the 7-16 age bracket.

Programming

Many actors seem to focus solely or primarily on programming. According to the student teachers, this can involve school students working on creating RCO alarms, programming a Microbit or Lego robots. Other common activities noted by the student teachers are CAD programming, Tinkercad in combination with laser cutters, robot building with Microbit and Strawbees, Python programming for colour coding in RGB for LEDs in imagiCharm, etc. The STEM actors describe how school students get to follow instructions, practise technical concepts, compare with images, and then evaluate their own work. According to the student teachers, many of the actors have become specialised in getting school students to encounter programming and various digital tools – with the aim of developing digital skills. Programming projects are aimed at all ages.

Innovations and creativity

The student teachers also report that many STEM actors are keen to emphasise the importance of allowing school students to work on innovations in order to develop creativity and the ability to work creatively. A common approach is that school students are given a task to develop something that already exists, but in a “different direction”. According to the student teachers, the STEM actors want to focus on practical activity and creativity; they want the school student to be able to use tools, materials, etc. This bears out the premise that school students can develop knowledge about how one gets ideas and how one can develop one’s creativity.

History of technology

Another common content item identified by the student teachers among the STEM actors is the history of technology perspective. It can be found not only in museums with a special focus on history but also in other actors who seem happy to reconnect with how technology has evolved and changed over the years. The student teachers note that it often relates to the development of everyday objects and different built-up environments.

Technology of the future

Just as often as actors are eager to capture historical changes, the student teachers relate that the actors want to set their sights on the future. According to the student teachers, the STEM actors talk about the importance of school students gaining insight into the new technologies of today and those of the future. The descriptions provided by the student teachers indicate that the actors are optimistic about technology, and most of the student teachers also expressed this view in their analyses. In terms of the actors’ view of the future, AI, space technology and the use of robots seem to be the technologies where it would be most important to acquire the appropriate knowledge.

Specific space theme

At a number of STEM actors, the student teachers found what they interpreted as a specific focus on space. The actors seem to have chosen to relate in various ways to what is happening e.g. on Mars and as regards technology that makes space travel possible.

Sustainable development

Most student teachers noted that the STEM actors want to highlight content linked to sustainable development; the actors also see this in some way as their distinguishing characteristic. However, this aspect seems to be mainly about sorting, reuse and resource efficiency in regard to the materials used in the construction processes within their own activities. The student teachers relate how the actors explain how they encourage students to sort leftover materials for recycling and sustainability – they also relate how they let the school students use recycled materials, including ordinary things that all students can find at home. At some actors, greater attention is paid to highlighting the 2030 Global Goals. The student teachers emphasise how the goals are used as a starting point for the activities at many STEM actors. This may take the form of the way in which the problem-solving task can start in a problem related to the global goals. The school students are then encouraged to help solve the problem by building a prototype. For example, students are tasked with building a mini-power plant or solar cells, usually by following a given set of instructions.

Discussion

The purpose of this case study is to investigate what impressions, experiences and perceptions aspiring subject teachers in technology, science or mathematics obtain from the encounter with STEM actors. These are impressions, experiences and perceptions that may colour their future teaching role. The question that was asked initially is what emerges from student teachers' reflections about the encounter with a STEM actor.

Student teachers arrive at a view of STEM actors as a valuable complement to school-based teaching in science and technology, which is a common view in research into science and technology teaching (Adams & Gupta, 2017; Melber & Cox-Petersen, 2005; Carvalho, 2021). The student teachers argue in favour of the actors' environments and their equipment, but also their teaching methods and commitment. This is something that has also emerged in previous studies, and which has proven fruitful for school students' learning (Lavie Alon & Tal, 2015; Bamberger & Tal, 2007). A majority of the student teachers state that they share the view of the STEM actors' aims in the latter's operations, that teaching should generate interest and curiosity and should lead to more young people being interested in career paths in science and technology. This is an approach that is clearly present among STEM actors, and which is also borne out in larger societal contexts (Zolotonosa & Hurley, 2021). The student teachers also value the STEM actors' continuing education for teachers, not necessarily for themselves but for colleagues who lack subject knowledge. The student teachers' statements rarely evince a critical attitude towards the STEM actors and their various operations; it becomes clear that the underlying views and values are shared. The STEM environments are appreciated by the student teachers; this is also borne out in other studies (Avraamidou, 2014; McGinnis et al., 2012).

Focusing in particular on the teaching in technology, the following is evident. In the student teachers' descriptions, one can detect a view of the school's formal teaching in technology as being insufficient to arouse school students' interest in the subject. They see active technology teachers as lacking the skills to show how much fun technology is and to create commitment. They view the schools as lacking in satisfactory equipment. This is a viewpoint confirmed in previous studies (Adams & Gupta, 2017). The specific technology content presented by the actors is not significantly different from that taught in a formal school setting. Many schools have access to both teaching materials and equipment that direct the teaching specifically to pneumatics, mechanisms and programming. Common elements of schools' technology teaching are a history of technology perspective and space themes in terms of looking to the future. Work on developing technology with innovative elements and a lot of hands-on construction is also common in schools' technology teaching. The technology content offered by the STEM actors is thus in itself nothing new or remarkable, as the student teachers also note. Admittedly, there are more materials and equipment, but the technology content itself is nothing spectacular. Regarding the technology content, there is even some criticism among the student teachers about e.g. the lack of theoretical elements. However, one thing is borne out by the student teachers despite everything: the student teachers' analyses find it self-evidently important (and this is also confirmed by the STEM actors) that school students should receive teaching in technology that is *fun*. The basic assumption that school students must encounter technology teaching that is fun if they are to become interested seems to be already strong among the student teachers; but it is also further reinforced by the STEM actors. Among future technology teachers there is thus the belief that school students find technology teaching boring; this may be seen as a basic assumption that risks becoming entrenched further.

The reflections of the student teachers after the encounter with the STEM actors can be summarised as follows. The student teachers do not seem to think that they themselves lack subject competence. However, they become convinced that the formal school setting fails to make the subject of technology fun and interesting enough. The student teachers are not completely convinced that doing (construction), i.e. practical work, is always what should be most important. Rather, they see shortcomings in theoretical foundations as problematic and suspect that there is an excessive reliance on materials and equipment. Nevertheless, they come down strongly in favour of the view that the teaching must contain engaging, fun and interesting elements and that it requires subject competence of the teacher. The student teachers are undergoing a teacher training course which includes encounters with STEM actors as one of its elements. The encounters may be said to have resulted in a view that technology teaching in a formal school setting is insufficiently interesting, engaging and fun. They themselves look forward with great confidence to teaching technology and they seem to want to make use of the STEM actors' environments and their commitment.

It became clearly that both STEM-actors and the student teachers themselves strives for to reach and give all young people the opportunity to get involved and interested in STEM. Earlier research (for example Archer et al, 2022) describes how interest and motivation for STEM among young people is strongly related to their culture capital (specific STEM capital). That is debated with relation to Bourdieu's theories about habitus and capital (for example Bourdieu, 1986). In relation to such theories and results, both how STEM-actors choose to organize their activities and how student teachers habitus give strategies within STEM, could be opportunities for further research. Likewise, it could be interesting to study if there is a difference in 'impressions' between student teachers with a specialism in science or mathematics rather than technology.

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Teachers' attitudes towards the amendments in the Design curriculum: a critical overview of the approach and findings of the study

Anriët van Deventer, University of Pretoria, South Africa
Raïta Steyn, University of Pretoria, South Africa

Abstract

This article[1] refers to the South African Design teachers' attitudes towards the implementation of the 2020 Section 4 amendments of the Design Curriculum and Assessment Policy Statement (CAPS). The purpose of the article is twofold: first to establish the necessity for *awareness* of the teachers' attitudes towards curriculum changes, especially when they are unexpected and abrupt. Secondly, to demonstrate the importance of *awareness* among educational authorities about the role of transparent discussions on the nature, purpose, and consequences of their relevant decisions before their final implementation. To this end, the article discusses the amendments and their differences to the former curriculum. The role of the Design teachers' positive attitude towards curriculum changes, especially in dealing with challenging pedagogical issues and communicating creative motivation to learners, is critically assessed. Theoretically, the study was guided by *Ubuntu* philosophy and the South African democratic principles while methodologically, based on a qualitative data collection process, the *attitudes* of Design teachers from seven selected schools have been individually examined. In conclusion, the teachers' heterogeneous responses have indicated that their opinions do not reflect the *à priori* governmental acceptance of the amendments.

Keywords

South African education, Curriculum changes 2020, CAPS FET Design, Design teacher, attitude, Ubuntu.

Introduction

This study is part of a comprehensive research project on applying Design Thinking (specifically its *process)* in the nationally implemented subject of Design education. In the context of the *Fourth Industrial Revolution*, the focus is on initiating, accepting, and implementing change among involved parties through *collaboration,* which is an essential factor in acknowledging innovation, embracing *change*, developing adjusted *attitudes*, and promoting new skills (Steyn, 2020, p. 338). The subject matter of the thesis was critically analysed and evaluated based on a qualitative case study conducted in the context of South African Design education policy guidelines. During the fieldwork, it was found that the Design teachers' attitudes differed pointedly in response to the new changes in the curriculum. The documenting of the relevant

[1] The article is based on the PhD thesis by Anriët Van Deventer, under the title: 'Teacher engagement with the process in Design: policies, problems, and visions', submitted at the University of Pretoria in November 2021.

views emphasises the value of this article, which we believe may assist the DBE in being more flexible when applying revisions in future.

Contextualisation

In the democratic South African education system, *Curriculum and Assessment Policy Statement* (CAPS) is reviewed and amended every seven years. In addition, the *Design Guidelines for Practical Assessment Tasks* (PAT) are annually reviewed and adopted. Therefore, before the South African government declared the *National Curriculum Statement Grades R-12* as a working document in 2012, many dedicated collaborators had contributed to the goals and vision to achieve the ideals of Design education in South Africa.

With reference to the subject Design in Grade 10 and 11, the CAPS amendment document was published by the *Department of Basic Education* (DBE) as *Arts Subject Quality Improvement* in 2019 and implemented in January 2020. Evidently, in the context of educational changes in the democratic South Africa, the two parties that need to collaborate in decision making and its implementation are the education authorities i.e., DBE and facilitators, the Design teachers. From this point of view, both parties – the government and the Design teachers – have a common interest, the transmission of knowledge for the benefit of the learners. This is reflected in the CAPS document which describes the Design subject as “a creative problem-solving process” that includes the study of design theory and practice. This process involves the following steps: “problem identification, planning, research, innovation, conceptualisation, experimentation, and critical reflection”. Ideally, according to CAPS, “Design equips learners with crucial life skills, such as visual literacy, critical and creative thinking, self-discipline, and leadership”. It also encourages learners to be resourceful and entrepreneurial, to strategise and to be team players.” (DBE, 2011, p. 8).

The article discusses the factors that influence Design teachers’ attitudes towards amendments and changes with the aim:

1. to promote awareness among educational authorities about transparent discussions on the nature, purpose, and consequences of decisions before being implemented.
2. to inspire a positive attitude in Design teachers towards curriculum changes, especially in the context of creative and critical thinking process regarding challenging and motivation issues.

Stemmed from the research are the following questions:

1. What are the Design teachers' attitudes towards curriculum changes?
2. How do Design teachers experience the new curriculum amendments by the DBE?

To this end, we present a review of selected relevant literature that underpins the discussion on this topic followed by the main reasons for the required adjustments to CAPS Design. The theoretical framework, case study design, methodology and a comparative review on prior policy alignments are included. The updated framework of the evaluation programme for Design Grades 10 and 11, divided into groups is also described. Finally, a conclusion drawn from the way DBE has introduced and communicated the Design curriculum changes to the teachers will be presented followed by suggestions for improvements.

Theoretical Background (Literature Review)

A comparative overview

Teachers' attitudes towards innovative thinking and changes have been discussed on an international level as well. With reference to Indonesia, Retnawati, Munadi, Arlinwibowo, Wulandari, and Sulistyaningsih (2017, p. 205), having identified certain barriers to teachers' understanding change, recommended that curricula should be amended in consideration of teachers' negative stigma to change. In consideration of individual factors, which may control the mind opening to change, amendments should be indicated with precision and a clear knowledge of new vicissitudes well understood.

From a comparative point of view, regarding curriculum changes in Zimbabwe, Milondzo & Magongoa (2018) (cited in Chimbunde & Kgari-Masondo, 2020, p. 36) identified challenges in the implementation of Design (subject) as problems related to the teachers' concerns, in terms of "beliefs, attitudes, preparedness, resistance", and unskillfulness. From their viewpoint, Chimbunde & Kgari-Masondo (2020, p. 36), state that teachers are opposed to the changes in general and how they prominently voice their concerns about the challenges experienced when implementing amended curricula. They found that "… countries with centralised curriculum development permit disparities in the interpretation of the curriculum as it is taught in the classroom by teachers who are not consulted". Nonetheless, the Chimbunde and Kgari-Masondo's study (2020, p. 36) reveals that it cannot be assumed that teachers are as resistant to change as previously believed (Gudyanga & Jita, 2018). Based on 54 international sources on teachers' reactions to curricula changes, Janko and Peková (2017, pp. 33-52) argue for successful curriculum changes implementation, teachers' attitudes are crucial determinants and that, depending on their socio-cultural context, may differ.

As for South Africa, Carl (2005, p. 223) emphasises the difficulties of defining teacher engagement in a simple, direct way, as the nature and viewpoint of a teacher' engagement often is determined by one's personal conceptualisation of the curriculum aspects. In addition, the level of the educational authority and the teachers' level differ fundamentally in terms of the macro-curriculum aspect at the national level and the teachers' micro-aspect narrowed at class level. As such, according to Carl (2005, p. 223), the phenomenon has already been widely discussed in the relevant literature such as Connelly & Clandinin, 1984; Imber & Neidt, 1990; Elbaz, 1991; Fullan & Hargreaves, 1992; Haberman, 1992; Fullan, 2001 and Carl, 2002. In his study on Arts and Culture teacher's experiences to curriculum changes, Lombard (2012, p. 165) stresses that it is critical for teachers to first acknowledge curriculum changes. This step should take place before focusing on resources and teacher support in terms of "making sense of the novel notion by restructuring existing beliefs and knowledge".

Nation Building through Education: The Role of *Design*

In the process of building a state-nation in Europe during the 19th century, the correspondent educational projects, and curricula focused on promoting a unifying national consciousness in a homogeneous society in terms of language, religion, and above all a common historical past. In this context, the process of national unification and integration was achieved mainly through political institutions and mainly *education.* These approaches, however, on the one hand have cultivated a strong bond between its members, yet, at the same time, they create a strong element of separatism and differentiation between “Us” and the “Others”. (Sansaridou-Hendrickx, 2005: 126-142). In the South African context, these factors are inapplicable.

In South Africa, after the fall of the *Apartheid* regime, in 1994 and under the leadership of Nelson Mandela, the country moved into a process of reconciliation and equal civil rights and opportunities. This multi-racial, multi-lingual, multi-cultural new-born nation, accurately labelled *Rainbow* nation, had to build, and sustain a collective national identity among its heterogeneous social entities and its members. To this end, the state set in motion all available institutions, private and public, and above all on the educational authorities. For the South Africans, thus, the endeavour has not been easy as numerous challenges and problems continue to complicate the implementation of relevant civil rules, laws, regulations, and curricula. Understandably, to develop a national consciousness in the context of its socio-cultural realities, the educational system has based its teaching and learning approaches on a broader value system than the conventional national principals. Based on the South African Constitution, the CAPS (2011, p.5) infuse the principles and practices of social and environmental justice, human rights, and inclusivity underestimating communication difficulties. However, as Steyn (2019, p. 164) states “the existing multicultural society and the multilingual inclusive system of communication in South Africa impose additional challenges” for proper communication within the framework of educational transformation. In this context, human feelings should be respected especially when the parties involved are communicating through power related positions and roles, in this case, the South African educational system and functions, especially in decision taking processes.

In principle, thus, the reformed curricula promote humanities through democracy. Consequently, educators of Visual Arts and Design, have adopted these principals by integrating them in the practical application of their teaching, as illustrated through *critical thinking and freedom of expression*. This effort for inclusion and awareness in the interaction between “us and the “others” at humanity level is illustrated by the analysis of the data, the relevant interviews, personal and group participation, as well as by the active involvement of the learners through their creative and critical thinking applied in their artworks.

Why Ubuntu ideology?

As for the ideological framework of the study, the *Ubuntu* philosophy is chosen as it reflects the African socio-cultural tradition and moral principles. Translated in English as *Humanity*, Ubuntu is a Nguni Bantu term which defines the African collective identity, and often justifies Afrocentric views versus colonisation policies. Letseka describes Ubuntu as “normative in that it encapsulates moral norms and virtues such as kindness, generosity, compassion, benevolence, courtesy, and respect and concern for others” (Letseka, 2000, pp. 179–180). Semantically, Ubuntu can be more or less related to “human-kindness” or “being human”, an ideology that encapsulates ”the substance of collective ethos” (Odari, 2020). According to Chimbunde and Kgari-Masondo (2020, p. 4), “the *Ubuntu* philosophy is a moral theory and a worldview”, as it speaks to the very essence of being mortal. A moral theory provides a precise framework for why a *certain* action is wrong in a *certain*, relevant socio-cultural and religious moral context. In return, kindness is universal. It can traverse ethnic, social, cultural, and political boundaries through proper communication.

Furthermore, according to Chimbunde and Kgari-Masondo (2020, p. 4), values and education are interconnected. In our view, since human kindness is connected by definition to *Humanity* - from the Latin *Humanitas* meaning “kindness” “human nature”, “culture” and “refinement” (University of Notre Dame Archives, 2021), it should be pedagogically promoted and applied accordingly in human communication. As we weight social values and morals with similar criteria, the *Ubuntu* philosophy is applied in this study as value-driven, incorporating human-kindness to assess human reaction to changes that need to be implemented. In line with the above principles, linking the reality of being human to different attitudes experienced by the Design teachers towards change, might be viewed as a natural human response to modification. If a typical reaction towards change is resistance, then change can be seen as a threat to some, making it difficult to accept it at first.

Consequently, from an educational perspective, we used the *Ubuntu* ideology as the main ethical criterion to understand and assess the humanity of the Design teachers in terms of their actual teaching, their theoretical frameworks, personal concepts, beliefs, and emotions. The research has paid special attention to the ability of the teachers to control personal emotions and exercise their pedagogical professionalism by way of objective interpretation of curricula and the application of relevant methods and approaches. Furthermore, Van Veen, Sleegers and Van De Ven (2005, p.918), and Van Veen and Sleegers (2006) examine how a teacher's professional identity is at risk in the current reform context, as well as how emotions play a role. The *Ubuntu* philosophy which serves as the theoretical framework for this article, is supported by the findings of the scholars above.

Former *SBA* versus 2020 amendments

In 2014, with the implementation of CAPS, the subject Design was introduced in the government and private schools as well as in the *Independent Education Board* (IEB). For each subject, the CAPS document, describes, amongst others, the specific aims, time allocation, overview of topics and the weighting, processes, and procedures of the assessment tasks. The *School-Based Assessment* SBA tasks include tests, exams, projects, practical tasks (i.e., preparation, planning, and the making of a product). These tasks refer to the *Design Process* (Topic 1*)*, the *Design Product* (Topic 2) and the *Design in Context* test/exam (Topic 3) (DBE, 2011, pp. 44-45).

The formal assessment tasks before the 2020 amendments, in Table 1, are explained as follows:

- Six formal *SBA* tasks: three practical tasks, two tests and one examination on theory, completed during the school year weighing 25% of the total mark for Design in Grades 10, 11 and 12 respectively.
- The end-of-year assessment component includes: 1) a Retrospective Exhibition containing the year’s three practical tasks and three assignments 2) a written examination and 3) a practical examination (i.e., *process* and a *product*). Collectively, these three parts cover the remaining 75% of both Grades.

Table 1: Before 2020 amendments: formal assessment, Grades 10 and 11. Source: DBE (2011, p. 45)

<table>
<tr><td colspan="1">Formal assessments (25%)</td><td colspan="3">Internal end-of-year examination (75%)</td></tr>
<tr><td>SBA – during year</td><td>Retrospective Exhibition</td><td colspan="2">End-of-year examination papers</td></tr>
<tr><td>25%</td><td>25%</td><td>25%</td><td>25%</td></tr>
<tr><td>• 3 PATs: 100 x 3
• 2 theory tests: 50 x 2
• 1 theory examination (mid-year): 100</td><td>• Exhibition/presentation of year's work (PATs 1 – 3): 70
• 3 assignments (Design in a Business Context): 30</td><td>Written examination
Design in Context
Grade 10: 2 hours (100)
Grade 11: 2½ hours (100)</td><td>Practical examination:
24 hours (estimate): 100</td></tr>
<tr><td>Term 1:
1 practical assessment task (50 process + 50 product) +
1 theory test (50)</td><td>Term 2:
1 practical assessment task (50 process + 50 product) +
1 theory examination (100)</td><td>Term 3:
1 practical assessment task (50 process + 50 product) +
1 theory test (50)</td><td>Term 4:
1 examination (2 papers): Paper 1 : Theory (100) +
Paper 2: Practical (50 process + 50 product) – done during the 4th term</td></tr>
<tr><td colspan="4">Promotion mark: Add raw marks and totals of assessment tasks from term 1 to term 3 and convert to 100 + retrospective exhibition and research (100) + paper 1 (100) + paper 2 (100) = Total of 400</td></tr>
</table>

The late Chief Specialist for Arts subjects in the DBE, Manana (2020, p. 5), explained why CAPS Design amendments were necessary:

- to strengthen and improve the quality and effectiveness of assessment as stipulated in *CAPS* Section 4 for Grades 10 and 11 from January 2020;
- to improve the weighting of marks per topic versus the teaching time spent per topic;
- to determine the marks allocated per topic;
- to address assessment overload;
- to revise and improve the forms of assessment;
- to align the differing policy and layout within the Arts subjects;
- to reduce curriculum overload; and
- to strengthen curriculum coverage.

Comparable to the former SBA tasks above, Table 2 displays an overview of the amended 2020-SBA program for Design Grade 10 and 11. The amendments include: relevant taxonomies regarding cognitive levels, the total number of tasks allocated per term and completed per annum, and the weighting of assessment tasks in terms of time and mark allocations, and lastly, content coverage. The tasks are broken down as follows:

- Five formal SBA tasks: two practical tasks, two tests and one examination on theory, completed during the school year weighing 25% of the total mark for Design in Grades 10, 11 and 12 respectively.
- The end-of-year assessment component includes: 1) a practical assessment task 2) a written theory paper, and 3) a retrospective exhibition of the year's work made up of products made in Terms 1 and 2 (this excludes the process). All three parts cover the remaining 75% of both Grades.

Table 2: 2020 amendments: formal assessment, Grades 10 and 11. Source: Manana (2020, p. 12)

GRADE 10 AND 11 FORMAL ASSESSMENT FOR DESIGN			
SCHOOL BASED ASSESSMENT (Internal) 25% 150 Marks + 200 Marks + 50 Marks= 400 converted to 100 Marks (SBA)			TERM 4
TERM 1	TERM 2	TERM 3	
TASK 1 THEORY TEST 50 Marks	TASK 3 THEORY EXAM 100 Marks	TASK 5 THEORY TEST 50 Marks	TASK 7.1 END-OF-YEAR EXAM P1. THEORY EXAM 100 Marks
12.5%	25%	12.5%	50%
TASK 2 PRACTICAL PROCESS Topic 1 100 Marks	TASK 4 PRACTICAL PROCESS Topic 1 100 Marks	TASK 7.2.1 END-OF-YEAR EXAM P2 PROCESS (50) ⇨	TASK 7.2.2 END-OF-YEAR EXAM P2 PRODUCT (50)
25%	25%	25%	25%
TERM MARK: 150	TERM MARK: 200	TERM MARK: 50	EXAM MARK: 200
⇩	⇩	TASK 6 PRACTICAL ASSESSMENT TASK (PAT) (Continuous assessment from Term 1 – Term 3)	
TERM 1	TERM 2	TERM 3	TERM 4
PRODUCT 1 Topic 2 100 Marks	PRODUCT 2 Topic 2 100 Marks	PAT EXHIBITION PROCESS (assessed in term 4) ⇨	PAT: EXHIBITION 100 MARKS Process & exhibition (50)
25% ⇨	25%	⇨	internally assessed Product 1 + 2 (50)
100 Marks (SBA) + 100 Marks (PAT) + 200 Marks (EXAM) = 400 TOTAL Marks			

In summary, amended SBA contains one task less. The practical projects completed in Term 1 and Term 2 are recorded as part of the SBA mark while the products are only reflected at year end. Therefore, the *Design Product* is recorded as part of the PAT mark but calculated only at the end of the year. The Term 3 practical task has fallen away and has been replaced by the *Design Process* of Term 4's practical examination. The *Process* component is completed in Term 3, but the mark is recorded as part of the examination mark, i.e., in Term 4 (Manana, 2020, p.5).

CAPS Design changes versus attitudes?

The term "change" and its synonyms alteration, modification, reworking, revision of the *state quo* is conditioned. As for "attitude", among others, it refers to "frame of mind", "outlook", "review", "reaction", "standpoint", "opinion", meaning different perspectives[2]. In the context of our research, an *attitude* is considered as an internal individual behavioural response to an inclination to *reply* positively or to be hostile to external variables in a person's life (for a definition, see Ajzen & Fishbein, 2005, p. 209). In our opinion, in a *dialectic* discourse between *thesis* (*status quo*) and *antithesis* (change) any amendment (change) is progressive and usually evokes mixed feelings towards a proposed improvement. In their discussion on the theory of dialectics, Baxter & Braithwaite (2010, 48-66) argue that for a positive attitude and agreement a constructive discourse between partners is essential.

[2] Merriam-Webster, 2020

Nonetheless, an attitude implies also a critical sense and approach. Opposing *change*, in general, is a human reaction deriving from fear of the unknown which is a natural human reaction. Therefore, the fear to lose the comfort of what one knows, causes resistance to change (Issah, 2018, p. 1). In the case of CAPS Design, most teachers have indicated they know the existing curriculum as they have worked out everything according to their understanding of the document policy. *An attitude* then conv*eys a* logically subjective *reaction to change*, whether positive or negative, which directly impacts on the acceptance or not of the new amendments and *changes* towards the 2020 CAPS Design document. To better understand the Design teachers' attitudes towards change, we present an overview of the causes of challenges.

Causes of challenges

The likelihood of numerous challenges emerging worldwide, due to implementing any new curriculum changes or reforms to established systems has stimulated great interest in academic spheres, accelerating research in curriculum changes and implementation thereof (Geisinger, 2016, p. 245). In line with this, Steyn (2020, p. 338) refers explicitly to the “lack of recognition and progress of art at all levels of the modern education system”. That ‘lack’ has been referred to, discussed, and attributed to the “serious ‘neglect’ and incapacity of the educators themselves to demonstrate art achievements on an ‘empirical’ level”. Thus, Steyn’s (2020) observation might explain the ‘neglect’ of South African Design teachers and the lack of opportunities for their voices to be heard and their inputs to be effectively implemented. Finally, Chimbunde and Kgari-Masondo (2021, p. 2) noticed in their literature that the main challenge was the ongoing *top-down approach* in the planning, design, and changes to the curriculum. This point further emphasises the need to involve as many stakeholders as possible, including Design teachers, whose contributions and inputs may fill the gaps and concerns when changes are to be made.

Research methodology

In the context of *Ubuntu* and its application in the real world, events are examined with a more detailed search into African humanness and interdependence between the individual (the One) and the community (the Others) (Mabovula, 2011, p. 40).. In the collective African worldview, individuals are intrinsically entrenched in a system of social and interdependent interactions and never considered as solitary individuals (Sefotho (2018), cited in Ngozwana, 2019, p. 295). This shared experience of life facilitates the interaction between individual and environment. As a result, the environment functions as a defining attribute of individuals (Anderson, Reder & Simon, 1996).

According to Yin (2009, p. 15, as cited by Arnell, 2014, p. 13), "case study researchers focus on the how and why of a research”, as they allow for a more in-depth exploration of real-life occurrences in their current context. This pragmatic contextualisation of the subject matter is essential both for the observer and the observed participants. Based on a purposeful sample, our case study consisted of eight Design teachers offering the Design subject in Grades 10-12 at high schools in the Gauteng province, South Africa. For our purposeful sampling, the eight Design teachers’ attitudes were individually examined and critically assessed. The rationale for the choice of this sample was threefold: a) to avoid a sample being altered to interviews with strongly pre-conceived ideas, b) to interview participants with vast Design teaching experience, and c) to interview participants from schools belonging to a different ranking category. To this end, the case study’s bounded context was set as follows: experienced Grades 10-12 Design teachers; schools' ranking categorised into high, mid, or low performing groups. These rankings were based on the past five years' National Senior Certificate (Grade 12) Design results. To ensure anonymity, the selected teachers' identities remained anonymous and participant codes (T1, T2, T3, etcetera.) were used.

For the purposes of this article, a mixed-method approach, i.e., quantitative, and qualitative methods were used. Open-ended, semi-structured questions were created for the interviews. The data was collected through interviews and an open-coding process was used to identify the dynamics of the participants' *attitudes* towards actual *change* effected by the CAPS amendments. Based on triangulation approach, the data was analysed in three sets: each participant was initially interviewed, then a follow-up questionnaire was distributed, and the CAPS document was analysed. Moreover, credibility can be achieved through persistent data triangulation (Elo, Kääriäinen, Kanste, Pölkki, Utriainen & Kyngäs, 2014, p. 8). Through the use of open-ended questions, data collection tools are also trustworthy and valid. The methodological accuracy and appropriateness of the qualitative research are referred to as trustworthy, validated by content analysis findings (Holloway & Wheeler, 2002:224). Furthermore, quality assurance measures credibility and trustworthiness.

The questionnaire comprised eight questions (See Table 3) which were sub-divided into three categories, and according to the nature of the theme. The theme, *Behaviour and Emotions* was broken up into four sub-themes and identified as follows: (a) General approach to attitude and change, (b) Announcement of change, (c) Feeling about the CAPS changes, and (d) Attitudes towards changes.

The questionnaire in Table 3 were divided into three parts. Part A (Q1-3) related specifically to the Grade 10 and 11 amendments of Section 4 of the Design CAPS and the teachers' feelings towards how the DBE projected these changes. Part B (Q4-6) concerned the Design teachers' attitudes and feelings towards these changes and how the selected teachers generally dealt with change in their lives. The last category, Part C (Q7-9), was structured in a way to measure the teachers' attitudes and tolerance to change, i.e., according to the 4-point Likert scale. The last question allowed teachers to voice their opinions on the relevant subject matter.

Table 3: Interview questions and questionnaire. Source: Anriët Van Deventer

<table>
<tr><td colspan="2">INTERVIEW QUESTIONS</td></tr>
<tr><td>1.</td><td>How do you feel about how the CAPS Design 11 changes were announced and implementation by the DBE?</td></tr>
<tr><td>2.</td><td>Do you understand and feel empowered towards the changes that must take place? Explain.</td></tr>
<tr><td>3.</td><td>How do you feel about Grade 11 CAPS Design changes implemented in Term 1, 2020?
3.1 Pro's
3.2 Con's</td></tr>
<tr><td>4.</td><td>How do you feel overall in your life about change?</td></tr>
<tr><td>5.</td><td>Please describe your attitude towards the latest changes to CAPS Design.</td></tr>
<tr><td>6.</td><td>Indicate your attitude scale [Cross out]:
<table><tr><td>Negative – Furious</td><td>Don't know - Difficult to adjust to the changes</td><td>Medium - Change is good but needs some more review</td><td>Positive – Much-needed change</td></tr></table></td></tr>
</table>

7.	Indicate your change tolerant scale *[Cross out]:* No tolerance to Change | Little tolerance but accept change | Medium tolerance to change | High tolerant to change
8.	Any general comments or feedback regarding *change and attitude*?

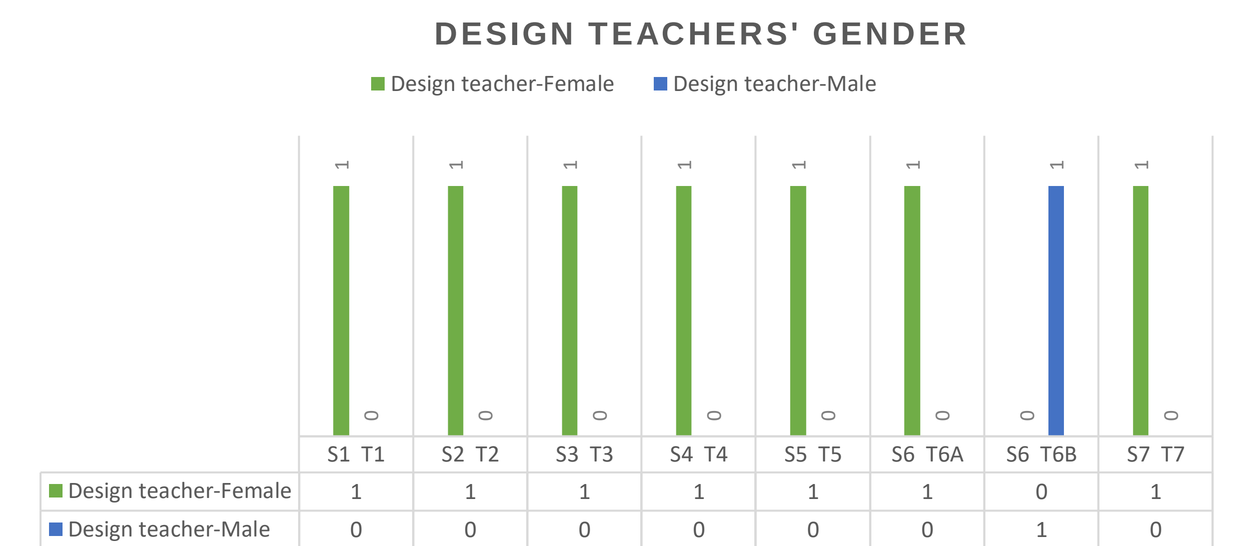
In addition, the recorded Zoom interviews were transcribed, allowing for our interpretation and confirmation, as well as clarifying questions that arose from the initial interviews.

Participant demographics Biographical information

Details about the teachers' qualifications, age, gender, years of experience in teaching the subject Design, and whether they had received any specific training on the practical implementation of the design process. The information gathered from this section was used to build profiles in the context of the participating Design teachers. Design teachers' gender is as follows: seven females and one male teacher (Table 4). This represents female dominance in Design education.

In addition, for the credibility of the research, the factual information, similarities and differences in terms of empirical knowledge and teaching strategies are divided into the following three categories and displayed in the graphs below: *1. Design teachers' gender, 2. Design teachers' age and the length of their teaching experience, and 3. Design teachers' qualifications*:

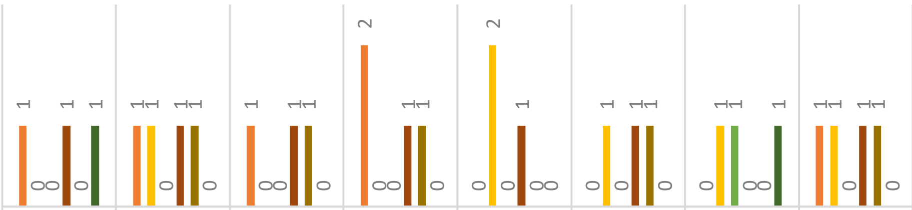
Table 4: Design teachers' gender. Source: Anriët Van Deventer



	S1 T1	S2 T2	S3 T3	S4 T4	S5 T5	S6 T6A	S6 T6B	S7 T7
Design teacher-Female	1	1	1	1	1	1	0	1
Design teacher-Male	0	0	0	0	0	0	1	0

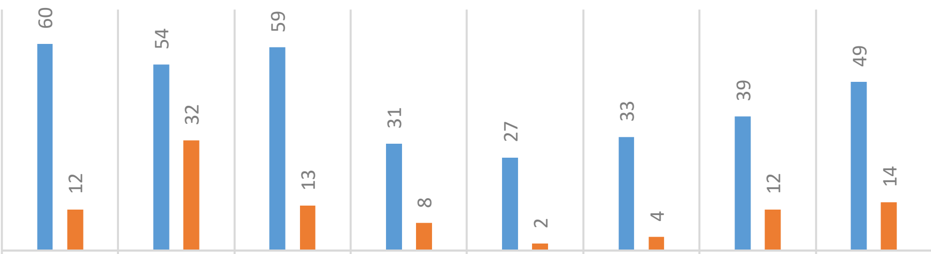
With reference to the Design teachers' qualifications (Table 5), it is noteworthy that only one teacher, T6B (male), has a Design qualification accompanied by other complementary technical subjects and a different qualification that is not Design related. Five teachers, T2, T5, T6A, T6B and T7 (females and one male), have a related Arts degree, and three teachers, T1, T3 and T4 (females), have an Arts Diploma. In addition, T4 and T5 both have post-graduate Arts or education qualifications.

Table 5: Design teachers' qualifications. Source: Anriët Van Deventer



	S1 T1	S2 T2	S3 T3	S4 ST4	S5 T5	S6 T6A	T6B T6B	S7 T7
Qualification-Diploma	1	1	1	2	0	0	0	1
Qualification-Degree	0	1	0	0	2	1	1	1
Qualification-Design	0	0	0	0	0	0	1	0
Qualification-Art	1	1	1	1	1	1	0	1
Qualification-Education	0	1	1	1	0	1	0	1
Qualification-Other	1	0	0	0	0	0	1	0

Table 6: A comparison of Design teachers' age and the length of their teaching experience. Source: Anriët Van Deventer



	S1 T1	S2 T2	S3 T3	S4 T4	S5 T5	S6 T6A	S6 T6B	S7 T7
Age	60	54	59	31	27	33	39	49
Years teaching Design	12	32	13	8	2	4	12	14

Table 6 compares the Design teachers' ages to the length of their Design teaching experiences (in years). These ages are included to reflect the age groups which are currently employed as Design teachers. Three Design teachers (T1, T2 & T3) are represented in the 50-60 years category, and T7 falls between 40-50 years. Three Design teachers (T4, T6A & T6B) stand for 30-40 years. Lastly, T5 falls into the age group 20-30 years. This puts half of the Design teachers (T1, T2, T3 & T7) above the age of 40, whereas the other half are young and upcoming teachers in the specialised field (T4, T5, T6A & T6B). Then, compared to the years of teaching, T2 stands out with 32 years of experience. Notably, although T1 is the oldest, their years of teaching

Design corresponds with T3, T6B, and T7 (younger in age), all of which have between 12-14 years of teaching experience. Lastly, T4, T5 and T6A, the youngest participants, have between 2-8 years of Design teaching experience. Hence, the comparison between the Design teachers' ages and their years of experience is not directly proportional to their age.

Table 7: Attitude scale. Source: Anriët Van Deventer

Negative – Furious	Don't know – Difficult to adjust to the changes	Medium – Change is good but needs some more review	Positive – Much needed change

The selected Design teachers were mostly positive about the new curriculum amendments, implemented in 2020. However, measuring teachers' attitudes towards the amendments using the 'attitude scale' (Table 7) indicated that four Design teachers were less positive as they felt that although change was good, it needed some more review. The remaining four teachers' attitudes were favourable towards a more drastic change.

Table 8: Change tolerance scale. Source: Anriët Van Deventer

No tolerance to change	Little tolerance but accept change	Medium tolerance to change	High tolerance to change

When measuring the Design teachers' open-mindedness to change, findings showed that only two Design teachers indicated their **tolerance to change** was *'high',* in other words, positive. Six Design teachers demonstrated their **tolerance** as *'medium'* (average/general) to change (Table 8). However, the four Design teachers that indicated that **change is good** (see Table 7) felt that curriculum changes needed more review. The remainder of the Design teachers (four) specified their **attitude as positive** and said the amendments to the curriculum were much needed.

Assumptions

The following assumptions about the participants were considered in this article:

1. The aim of using a single case study was to gather results that represents the real situation and the problem of the subject matter. Therefore, it is assumed that the selected eight Design teachers represented the voices of most teachers of Design education practice.
2. The selected participants had a professional level of Design teaching expertise and could successfully navigate the amendments to the curriculum.
3. It was believed that the selected participants would be truthful in their responses to the interview questions. Therefore, it was expected and believed that participants' responses to the interview questions would be honest.

Findings

The findings of this article are divided into the following four themes: (a) General approach to attitude and change, (b) Announcement of change, (c) Feeling about the CAPS changes, and (d) Attitudes towards changes.

Design teachers' attitudes to change in their lives in general:

The study's findings revealed that most Design teachers felt positive in general towards change, as it is needed for growth and progress. It has been established that most of the Design teachers were accepting the amendments to the curriculum: T1 stated that *"change is necessary and inevitable",* and T2 said: *"I am not afraid of change if it is viable and meaningful".* T3 appeared to be more cautious and specified that *"I'm sort of in a midway – it depends on the change".* T5 granted change as *"…sometimes good, and I adapt easily to difficult situations and change".*

Design teachers indicated dismay in how the DBE announced the changes to the curriculum

For certain Design teachers, the way forward should be for the DBE to conduct proper engagement through discourses with the teachers as responsible educators and role-players in curriculum development for the teaching and learning progress. In support of the *Ubuntu* ideology as value-driven criterium, to evoke positive reaction to changes, they need to be pre-discussed, understood and amended before implemented.

For example, T2 asserted that: *"[DBE] wanted to avoid double-dipping, but this does not seem to be a successful approach"*. T3 received the amended document late and said: *"[the amendments] could have been discussed with us a little bit more by the department".* T5, a novice teacher, felt that: *"the changes of CAPS Grade 11 hadn't affected me a great deal as I had just started my career".* On the other hand, T6A, T6B and T7 were very positive about how the changes were introduced and stated they had a lot of support *("subject facilitators provided further support").*

The following are the condensed findings from Design teachers' points of view regarding their feelings towards the amendments to the curriculum.

The study's findings revealed that most Design teachers, taking into consideration '*pro et contra*', felt that changes to CAPS were most needed and welcomed. T1 said: *"I have an understanding of the changes as they have come to me".* T5 postulated: *"at least the [learners] have more time to work on their portfolios and do the developmental drawings and preparation work more thoroughly".* However, T2 stated: *"the contrary is not thoroughly thought through – change for the sake of change".*

The teachers' attitudes of acceptance of the implemented changes to the curriculum as anticipated

The findings showed that the teachers felt that curriculum amendments were needed. The findings also established that the authors anticipated that the modifications to the curriculum would be accepted by Design teachers. Therefore, they had no choice but to implement the amendments and continue teaching the new expectations of the implementation. The teachers 'voices' are significant and should be noted. In support, Van Veen and Sleegers (2006, p. 86, cited in Eisner, 2000, p. 347) stresses that "Teachers need 'to feel a part of, if not in control of, the improvement process". Furthermore, these findings indicate that there has been a demand for new approaches to accommodate teachers' sentiments towards CAPS amendments. The Design teachers' statements below demonstrated that they expect early consultation before changes are made and scheduled for the curriculum's implementation. T2 emphasised *"the latest changes in CAPS Design [for me] are not very meaningful. The outcomes won`t be better, and I do not see this improving Design and Design knowledge at all"*. T4 indicated these *“changes do place less pressure on the [teacher], which in the long run does benefit not only the learners in many ways but also the educators' way of teaching and the quality of teaching that the learners will receive”*. Furthermore, T5 voiced that *“the latest amendments to Design CAPS are most probably going to differ from school to school; for example, I am ahead with my theory work thanks to online learning”.*

Lastly, the findings of the relevant study have demonstrated that the Design teachers’ ‘age group’ did not play a role in determining their attitudes to change. Participants appear to believe they have a role to perform outside of the classroom in terms of the curriculum, but feel that their voices ‘are not heard’. Similarly, Fullan and Hargreaves (1992), Carl (1994), Fullan (2001) and Kirk and Macdonald (2001) expressed the opinion that teachers felt they were constricted to the classroom and should be given opportunities to involve teachers in curriculum development. Hence, the Design teachers accepted the changes, and stressed that their opinions towards change are important and should not be ignored.

Recommendations

Based on the findings and the analysis of this study:

- The DBE should engage directly with Design teachers as primary stakeholders for inputs into future amendments and broadening the curriculum.
- The research established that the attitudes of Design teachers are often affected by the perceived (Design teachers) insensitive attitude of the DBE.
- The study pointed out that amendments to the curriculum were necessary as it brings forth a more balanced curriculum and offers protection for overload.
- Additionally, the revisions support Design teachers in teaching learners in the extra time available. For example, by allowing teachers to fill these gaps in the curriculum, such as concentrating on alternative methodologies.
- Finally, the curriculum changes have been designed and structured to contribute significantly to supplementing curriculum overload with more time to complete tasks.
- In answering the second research question: *How do Design teachers experience the new curriculum amendments by the DBE*, it will be noteworthy to observe consulting, input, and cooperation more inclusively. As we saw in the introduction, it directly affects Design teachers being left out, mainly where their voices should be heard. *What are the Design teachers' attitudes towards curriculum changes*?

Conclusion

The aim of this study was to analyse the Design teachers' attitudes towards the implementation of the formal modifications to the CAPS Design curriculum and assess the effect of their viewpoints on their teaching approaches. The selected Design teachers were optimistic about the 2020 Design Grade 10 and 11 curriculum changes and prepared to move beyond the identified negativity. As the authors engaged with Design teachers on various levels, their assumption is to report on the facts and make authorities aware of the experiences of those implementing the changes at the grassroots level.

With reference to the conventional way the educational system of a homogeneous national consciousness is built and promoted, the research has acknowledged the difficulties in unifying nationally, under common goals, the highly diverse in terms of language, culture, traditions, value-systems within the South African society. As a solution, it highlighted the need to identify globally recognised human values and integrate them in the decision-making and implementation processes in the South African educational system. In line with this, the article has portrayed the importance of the stakeholders' voices and those of the Design teachers to be heard and coordinated in terms of ideas, suggestions, proposals, and different viewpoints. In the framework of the *Ubuntu* socio-political ideology respected in South Africa, the study has demonstrated that implementing changes can lead to reliable positive outcomes, provided the interested parties are well-aware of the involved challenges and relevant problems. Proper knowledge and awareness, we believe, can be inspirational and motivational forces, both crucial factors in teaching and learning critical and creative thinking in Design.

The article encourages us to reconsider what comprises the inclusiveness of all stakeholders when new amendments are planned, proposed and implemented. Even if the government has worked with subject specialists, the new amendments are incomplete, acceptable or not, and partly satisfactory. Nevertheless, it is possible to construct and maintain the collaboration of different stakeholders.

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27.2

Design Thinking, An Examination of Epistemological Frameworks in an Area of Academic Study

William J. Gibbs, Duquesne University, USA

Abstract
The ambiguous identity of the digital media field, the ubiquity of media, and rapid and persistent technological change and innovation pose inimitable challenges for academic programs in digital media. Digitization of media is an underlying impetus for today's rapid innovation that compels related academic programs in higher education to re-examine themselves to keep pace and to better understand their epistemological foundations. Digital innovation helped spur renewed awareness of human-centered design to solve ill-structured, highly complex problems. Design and Design Thinking (DT) provide a potential framework to aid in academic program assessment. In this paper I explore precepts of design and DT as a potential frame of context to aid in curriculum design. I present a case study example that examines the process to assess a digital media curriculum using a DT framework, an iterative process involving students, faculty, and academic and industry partners.

Keywords
Digital Media, Design, Design Thinking, Design Process, Design Iteration, Human-centered Design, Assessment.

Introduction
Over the past 35 years colleges and universities worldwide created academic degree programs in new media, and a host of other titles. Many universities recognize that the field evolved into an established academic area and therefore offer related majors (Ryan, et al., 2014). New media or digital media, as it is commonly referenced today, involves an array of approaches and disciplines (Sterne, 2005), influenced by psychology, computer science, art, design, media studies, human-computer interaction and communications. Scholars differ about what constitutes digital media, which contributes to the field's indistinct professional identity (Huang, 2009; Peters & Nielsen,2013). Digital media curricula in communications, computer sciences, and art departments can have disparate emphases ranging from broadcast media to interactive applications and gaming, to visual aesthetics and artistic expression. In terms of topics, historical framework, literature, research and even definitions of the field, an introductory digital media course as part of a similarly titled major (i.e., Digital Media, New Media, etc.) offered through an art department will likely be quite different compared to an identically titled course and major offered in computer science or communications. This may also be true within academic programs of study. Within programs, philosophical viewpoints about what constitutes knowledge in digital media and how it can best be acquired often vary. The epistemological frameworks that determine relevant phenomena to study, methodological practices, types of evidence, research goals, assumptions and fundamental beliefs about the discipline, among other things, can differ (Brister, 2017), having significant implications for programs, faculty, and students. Differing epistemological frameworks as well as the breadth and diversity of curricula, while not uncommon in higher education, may be emblematic of the relative newness of digital media as an area of study, the ubiquity of media, and the lack of

clarity as to what digital media or new media represent. These factors are particularly noteworthy today as universities face much competition for students and, at the same time, they must increasingly demonstrate their value to students and ability to prepare them for professional life (Huq & Gilbert, 2017).

Compounding these issues, many digital media programs endeavor to be technologically up-to-date and at the forefront of innovation. Manovich (2001, p. 20) notes, "new media represents a convergence of two separate historical trajectories: computing and media technologies". The digitization of media is an impetus for pervasive innovation and change, transforming industries and related work methods and practices as well as consumer behaviors. The rate of change and innovation poses unique and complex problems for business and educational institutions, many of which have sought to expand their means for addressing them by turning to design, specifically Design Thinking (DT), to effectively respond to as well as think creatively and rationally about innovation (Chaplin, 2016a). DT is a human-centered, collaborative, and holistic design process (Willness & Bruni-Bossio, 2017). As Dorst (2011, p. 521) points out, "Design Thinking has gained popularity - it is now seen as an exciting new paradigm for dealing with problems in sectors as far afield as [Information Technology] IT, Business, Education, and Medicine." Applications of Design Thinking in education can be found from K-12 through graduate studies (Pande & Bharathi, 2020). Anderson et al. (2017) point out that while DT has been used among technology and consumer goods companies, hospitals have used it to improve patient experience and outcomes.

Purpose

In this paper I explore precepts of design and DT as a potential framework to aid in curriculum design. I present a case study example that examines the process to assess a digital media curriculum using a DT framework, an iterative process involving students, faculty, and academic and industry partners.

Background and literature

The Digital Media Arts (DMA) program was formed in the mid-1990s and it offered two study concentrations, Multimedia Development and Web Development. Students choose one concentration and must complete nine required courses (27 credits) and three elective courses (9 credits) specific to their chosen concentration. As the digital media discipline evolved and it became increasingly ubiquitous, the department faced constant innovation and rapid technology change. There were several external and internal influences that served as the impetus for a re-examination of the core foundations of the program, some of which are discussed below. These forces affected curricular decisions, teaching, resource funding, and ultimately the direction of a program.

External and Internal Influences

New and emergent industry practices and methods resulting from digitization proved to be disruptive external influences on the program. As technology and related methods changed, the program needed to adapt. Rapidly, industries and society in general acclimatize to digital content creation with eventually almost all media created digitally. Software and hardware became integrated and easier to use. Questions about teaching technical or craft skills (e.g., hardware, software) versus higher order thinking and problem-solving pose challenges for academic programs of an applied nature as the industry's need for craft skills is often at odds with university missions (Huang, 2009).

There are also questions about the extent to which digital media is perceived as a primary discipline or a subdiscipline. Golumbia (2014, p.54) points out that "the field of digital media can be arguably understood to be so wide as to encompass virtually everything." This creates uncertainty for individuals inquiring about these academic programs. It also alters the nature of the curriculum and course topics. In response to transformations spawned by media digitization, academic programs approached the study of digital media distinctly. For some programs, digital media was the primary or foundational concentration of study. The program culture and curriculum derived from core precepts of digital (programmable) media, new media theory, technology, media creation software as well as design and production. Conversely and perhaps more commonplace, many academic programs, in reaction to the pervasive impact of digitization on almost all disciplines, seemingly adapted aspects of digital media as a sub-domain wherein they educated students in a primary area of study such as communications and then helped them understand how new digital practices (the sub-domain) integrated to it. Because digital media impacts most disciplines, the degree to which it is a sub-discipline or a support discipline is particularly important, as this shapes the academic approach and nature of the curriculum. This was an unforeseen obstacle for the department and a key underlying facet in the re-examination of the curriculum. Questions arose about definitions, perspectives, and beliefs regarding media. At times, there was uncertainty about the extent to which courses should focus on digital culture, design, and computation more generally versus media in the context of media communications industries, mass media, advertising and public relations.

In response to these challenges, the DMA faculty endeavored to assess the major to ensure there was a shared epistemological framework and mission. It is not uncommon for faculty to possess diverse professional and academic training, often from outside the field. They may hold distinct philosophical views about what digital media are and the direction of the curriculum. However, this disparity in thinking about digital media was another unforeseen obstacle and key facet in decisions to partake in re-evaluating the curriculum. Without a shared epistemological framework, language and knowledge of a field's fundamental positions and assumptions, it is susceptible to influence and critique (Werner, 2018).

Digital media programs are influenced by other disciplines (e.g., computer science) that are generally stable and less disruptive to curricula. They are also impacted by industry "craft" knowledge and skills that are dynamic influences, susceptible to digitization, requiring programs to adjust rapidly. The challenges of curricula assessments and planning, already multifaceted are compounded by the effects of media digitization and exacerbated by the field's lack of clear identity

Design

Design is the realization of the human aptitude for intelligent action (Galle & Kroes, 2015). It is the purposeful creation of products and services that fit human needs (Norman & Klemmer, 2014). Design focuses on potentiality or "how things ought to be - how they ought to be in order to attain goals, and to function" (Simon, 1996). Key tenets of design include systemic thinking, focusing on individuals and listening to them to identify core problems, experimentation and ideation, testing, and iteration. It is the conceiving, planning, research, and making of things, such as products, ideas, interactions, services, systems, applications and more. People identify design as a process of thinking, germane to any profession (Nielsen & Stovang, 2015) and not solely the purview of professional designers. Gibbsons (2016, para 3) notes, that a human-centered "design approach proved to be a differentiator: those companies that used it have reaped the financial benefits of creating products shaped by human needs." There are several DT frameworks (Dam & Siang, 2017), one of which is the five-stage process model proposed by Stanford University's d.school. The model stresses a human-centered and holistic focus, moving from divergent to convergent thinking, collaboration, creating prototypes that are refined through successive design iterations and understanding the context in which design is to takes place. DT generally include the following stages:

Empathize: Design team attempts to identify the core problem(s) from the perspective of the people most impacted. It is essential to learn about the people affected by the problem - their interests, needs, behaviors, among other things.

Define: Analyze and synthesize the observations or data collected in the Empathize stage to fully understand the central problem(s).

Ideate: Design team generates ideas or possible solutions to solve the problem.

Prototype: Team produces multiple inexpensive versions of the design solution, as quickly and easily as possible. These "rough" versions of possible solutions help the team investigate the efficacy of ideas generated in the previous stage.

Test: Team thoroughly evaluates the completed design.

Despite growing interests in DT, it is not without critics, with some asserting that it is limited, and approaches design superficially (Chaplin, 2016a). However, proponents see it as harnessing a design methodology by multidisciplinary teams, often non-designers, to a broad range of ill-defined highly ambiguous innovation challenges (Seidel & Fixson, 2013). Moreover, it is a highly iterative process, based on learning through experimentation (Liedtka, 2015), and it can be used by non-designers, which is appealing for faculty committees of non-designers charged with designing academic programs and curricula. As Brown and Katz (2011, p. 381) note, "A competent designer can always improve upon last year's widget, but an interdisciplinary team of skilled design thinkers is in a position to tackle more complex problems."

Method

Five faculty members (design team) of the DMA program initiated the curriculum re-design process. It originated from informal conversations about changing dynamics of the field, courses, course enrollments, student progress and reactions to class activities, and how to adapt.

An important factor was how to begin. The team met initially and while the discussions were fruitful, many divergent work paths emerged. Members struggled about a clear direction, which was critical given the limited time the team could devote to the project.

Cognizant of the constraints under which the team had to work (i.e., existing faculty and research commitments, no external mandates), members endeavored to identify an approach that was readily understandable and straightforward to implement. Lawson and Dorst (2009) note that models depict processes and can help organize design work and enable non-designers to comprehend the practice, even if in a limited way. To provide understanding of the macro-level processes the team might engage in, one member explored influential instructional design models such as ADDIE (analysis, design, development, implementation, and evaluation) and curriculum design models such as Tyler's (1949) objectives model; and Saylor, Alexander, and Lewis' curriculum administrative model (see Saylor et al., 1981; Lunenburg, 2011). Additionally, outside the educational realm, approaches and practices such as The Frame Creation Model (see Dorst, K. and Stolterman, E., 2015) and Design Thinking frameworks were examined. The team ultimately chose a DT approach to frame their work because it seemed to provide an understandable approach about how to proceed. Moving from broad to specific concepts, which is characteristic of design thinking (Willness & Bruni-Bossio, 2017), it collected information from national and regional programs and then engaged in a self-study of DMA.

External academic program review: The team reviewed 56 digital media-oriented programs at 49 schools in the United States to learn about courses, program structures, language or terminology used, and program descriptions. Huang (2009) identified 182 digital media-oriented educational programs. Using Huang's list, the team initially identified programs with titles like the program, such as digital media, multimedia, interactive media, and media arts. A review of descriptions and courses was conducted to ascertain related programs. There were several programs with similar titles but quite different emphases. For instance, a program might be titled digital media, but it emphasized film or gaming. Additionally, the team conducted Internet searches for programs and collected the following information:

- Type of degree BS, BFA, BA, name of degree
- Total credits required
- College, School in which program is offered
- Department in which program is offered
- List of courses noting any concentrations
- Topics covered in courses
- Title of courses

Job descriptions: To obtain information about the types of "craft" skills and knowledge required by employers, two team members reviewed position announcements. They searched using keywords such as digital media, new media, multimedia, design - user experience, interface design, and web, photography, and video. They extracted keywords from these announcements related to required skills and knowledge.

Interviews

Faculty: A team member interviewed each of the DMA faculty (4 faculty members) to understand how they viewed the DMA program and their perception of its mission and goals. The interviews lasted approximately 1 hour, during which the interviewer asked them to briefly describe the program and define its mission and goals. Approximately 1 month after the interviews, faculty participated in multiple group brainstorming sessions.

Students: The team member conducted individual “exit interviews” with a small number of graduating students to obtain feedback about the program. In an open-ended discussion, the interviewer asked students to provide feedback about courses, the major, and the curriculum.

External programs chairpersons, faculty, and professionals: The team member interviewed 12 individuals external to the university who had knowledge and experience in digital media. As described earlier, the team reviewed 56 digital media-oriented programs at 49 schools. A team member interviewed five program chairpersons and three faculty members from those programs. The interviewer also interviewed four business and industry professionals. The interviews were conducted face-to-face, or by telephone or email.

Interviews with faculty and chairpersons focused on the following topics:

- Type of degree BS, BFA, BA
- College, School in which program is offered
- Total credits required
- Program and courses titles
- Program philosophy/emphasis, mission, focus, and goals
- How did program determine the topic areas in which to offer courses?
- Topics covered in courses
- Curriculum - types of courses, sequence of courses
- Program identity – how does the program identify itself e.g., news media, computing, art, etc.

Interviews with industry professional focused on the following:

- Knowledge and skills expected of graduates
- Titles of program and concentrations that attract interviewees when hiring
- Curriculum – courses or course topics that help graduates in the industry

Brainstorming Sessions

Over a sixteen-week period, the faculty who teach in the major met weekly for brainstorming sessions typically 1 hour. A facilitator presented an initial set of problems/issues related to the following:

- Program identity - mission, focus, and goals
- Program competitiveness and viability, relative to other programs in digital media
- Areas of the field for which students are being prepared
- Theoretical base that informs the curriculum
- Curriculum and programming issues
- Industry trends and their impact on teaching and learning

Data collection and analysis

The team reviewed 56 digital media-oriented programs at 49 schools in the United States and twelve of these schools were within the same geographic region as DMA.

Program titles varied. Digital Media was the most common title, with seven programs using it. Digital Media Design, Interactive Media, and Multimedia each occurred multiple times. Most titles were general in nature and did not focus on a specific media (photography, video). Table 1 presents a list of program titles. If title reflect the overall emphasis of programs, then design, digital, interaction/interactivity, and media are areas of focus in the 56 programs reviewed.

Table 1. Program titles.

Comm, Media & Technology	Digital Multimedia Design	Graphic Design	Interactive Media Studies
Computer Science/New Media	Digital Art and Design	Integrated Digital Media	Media Art & Design
Converged Media	Electronic Design & Multimedia	Interaction Design	Media Arts
Design for Interactions	Electronic Media	Interactive Design and Game Dev	Media Arts – Web Design
Digital Arts	Emergent Digital Practices	Interactive Design | UX | Experience	Media Arts & Technology
Digital Arts & Multimedia Design	Emerging Media Technology	Interactive Digital Design	Media Comm
Digital Design	Film and Digital Media	Interactive Digital Media	Multimedia
Digital Media	Film and Digital Technology	Interactive Media	New Media
Digital Media Design	Film, TV, and Media Arts	Interactive Media and Game Dev	New Media Design
Digital Media Production	Graphic and Interactive Design	Interactive Media & Web Design	New Media Interactive Development
			Web development

Most (50%) of the 56 programs were offered through the *College of Art and Sciences/Architecture*, followed by *Schools of Communication/Media* (24%), and *Computer Science* (10%). A smaller percentage were found in Management Information Systems (6%), Engineering (5%), Liberal Arts (3%), and General Studies (2%). Programs in *Arts and Architecture* offered courses with an art emphasis; programs in *Schools of Communication/Media* emphasize TV and news, writing, and programs in *Computer Sciences* emphasize technology and programming.

The primary program degree types were Bachelor of Arts (41%), Bachelor of Science (27%), Bachelor of Fine Arts (22%), and Bachelor of Design (5%). One school offer a Bachelor of Technology and another a Bachelor of Information Science.

To obtain a measure of the topics emphasized in programs, the design team compared course titles or areas of emphases of the *Multimedia Development and Web Development* concentrations to national and regional schools by searching the curricular of the 56 programs and noting course titles (e.g., video, animation, etc.). For example, in Table 2, of the 56 programs reviewed, 43 (77%) included Design in a course title at least one time. It should be noted that within some topics there was a range of sub-topics. *Design* includes design courses, web design, visual design, and interaction design, among others.

Table 2. 15 most reoccurring topics in curriculum by program

Most reoccurring topics	Percent of schools including course topic in curriculum
Design	77
Graphics | Illustration	70
Web	66
Video	59
Animation	52
Interaction | interactivity	52
Programming	50
Imaging	46
Multimedia	46
Photography	45
Production	43
Interfaces| HCI | UX	43
Audio	41
3D	34
Gaming	32

It appears that curricular are generalized. Rather than specializing in a specific topic area (e.g., video) programs cover several topics (see Table 2). On average, each program offered courses that address 8 of the 15 most reoccurring topics. Of the 15 most reoccurring topics, the fewest number covered in a curriculum is 4 and the highest number covered is 13. This does not mean that programs do not allow for specialization; within the reviewed programs, students can specialize. Interestingly, the words in many course titles tend to be media specific. The most popular terms do not emphasize processes, such as managing or designing.

Using the same procedure as when identifying areas of emphasis in all programs, the team reviewed 17 programs at 12 regional schools to identify topics emphasized. Table 3 shows the 15 most reoccurring topics by national and regional programs.

Table 3. Most reoccurring topics: National and Regional

Percent of schools including course topic in curriculum			
National programs (N=56)	%	Regional programs (N=17)	%
Design	77	Graphics/Illustration	76
Graphics | Illustration	70	Design	65
Web	66	Web	65
Video	59	Photography	65
Animation	52	Production	59

Interaction | interactivity	52	Animation	53
Programming	50	Interaction/interactive	47
Imaging	46	Video	47
Multimedia	46	Imaging	41
Production	45	Communication	35
Interfaces| HCI | UX | Mobile	43	Programming	35
Photography	43	Multimedia	29
Audio	41	Print	29
3D	34	Portfolio	29
Gaming	32	Audio	29

Job descriptions: To obtain information about the types of skills, knowledge and technologies employers required, the team reviewed position announcements from sources such as ZipRecruiter, HigherEdJobs.com, User Experience Professionals Association, Monster, and CareerBuilder. Table 4 presents a list of descriptions categorized broadly as Multimedia, Digital Imaging, Video & Sound Production, Web Design and Development, Interface Design & Usability, and UX – Interaction. Position descriptions tended to included references to theories, principles, methods (TPM), applications (APP) or applying principles, and tools (e.g., software, hardware) and these are indicated in the table.

Table 4. Skills and knowledge listed in employer position announcements

	Multimedia		
TPM	Multimedia, hypermedia	Multimedia Design/dev processes	Multimedia, new media theory
	Graphic Design for print and digital	Interactivity	Emerging Trends
	Web, branding, typography, layout	Best practices	Multi-platforms
	Analytics digital advertising	Social Media	Portfolios
APP	Media types; optimization	Compression, encoding, online del.	File formats-graphic, video
Tools	Media Design Software	Photoshp, Illustr, Premiere, InDesn	HTM, CSS, JS, Frameworks
	State-of-the-art technologies	Professional image acquisition	Lighting equipment
	Digital Imaging, Video & Sound Production		
TPM	Production, storyboards, scriptwriting,	Videography, film multiple settings	Documentary film
	Video and podcast production	Edit/optimization-vid-aud-images	Experience with media types
	Write stories to creative standards	Motion formats, visual approaches	AV streams; Organize assets
APP	Digital media compression, encoding	Formats and codecs; Transcoding	Stream, formats and codecs
Tools	3D Animation (e.g., 3d Studio Max)	Video and audio editing	Photoshp, After Effs, Premiere
	Video, cinematography	Professional video acquisition eq.	Proficiency with lighting
	Web Design and Development		

TPM	Theories, models, processes	Gestalt, Visual design principles	Color, composition, space, type
	Color theory; Information theory	Human perception-factors	Typography
APP	Web design, dev., eval start-finish	Web guidelines	Responsive desgn; Mobile-first
	Accessibility; Section 508; W3C	SEO	Analytics
	Wireframing	Flow diagrams	Site maps
	Use cases	High-level prototyping	Test, verify results and implt.
	Media optimization	File formats	All mobile platforms
Tools	HTML, CSS and Scripting; framewrks	Page layout, Styling Techniques	JS, XML, PHP, MySQL;
	Interface Design & Usability		
TPM	Usability Engineering	ID Theories	Design methodologies
	Navigational models; Infor arch.	UI development	Human Factors
	UI, layout, type, and iconography.	Gestalt	Human centric design
	Rapid prototyping and methods	Agile	Ui design trends; best practices
APP	Front End analysis, requirements	Research tech, interview, focus grps,	A/B Testing
	User interviews	Task analysis	User scenario development
	Card sorting	High-level use case definition	Usability techniques and tools
	UI/Prototyping, storyboards, doc.	High-level prototypes	Heuristic evaluations
	Wire framing	Flow diagrams	
	UX - Interaction		
TPM	UX processes	Interaction design; IxD Theories	UX experience design; HCD
	Research methods, tools; Eye tracking, user observation, task coding	UX research, Experimental design, Empirical evaluation; data analysis	Evaluation; Usability research studies, testing and information architecture
	UX methodologies/best practices	User action framework	User task analysis; Use cases
APP	Process-Flow; journey; affinity	Responsive design; mobile-first	Front-end and interface dev
	Personas	Card Sorting	Wireframes
	Development Methods; Agile	Web and mobile app design	File formats; Media optimize
Tools	Prototyping Tools	Mobile applications	
TPM: Theory, Principle, Methods		APP: Applications of TPM	Tools: Tools used

Interviews. A team member interviewed 12 individuals external to the university who had knowledge and experience in digital media. Table 5 present a summary of main points and categorization of their commentary. Key points about curriculum design include iteration or continual refinement, faculty involvement, and planning for change and the future.

Table 5. Interview commentary summary

Faculty involvement
Work internally within faculty resources - curriculum grounded in faculty expertise. Faculty came up with curriculum. Faculty with expertise in area of curriculum take ownership and share curriculum ideas with faculty.
Ask specific people to take charge of areas and report back to group.
Did not hire of external reviewers.
Characteristic of curriculum
Cohort program. Portfolio. Must include theory and development/production; theory courses and basics programming courses.
Offer an applied course each semester. Students should be able select courses based on educational-career path so they can discover their strengths and identity. Flexibly for students.
Making curriculum revisions
Define mission immediately. Identify general objectives so everyone “buys in”.
Generic course titles so you can change.
Survey professionals to help guide process. We compiled and studied existing program curriculum, talked to colleagues in other programs, and then met as a faculty to brainstorm.
Course and content decisions made by Chair with interested faculty and staff.
Try things and revise – convey that it is not the “final version.”
Make changes continuously. Meet often. Everyone needs to be involved. Be patient with the process. Takes time
Students
Students create a portfolio. Program should provide for students to evaluated so they can revise portfolio.
Scope
Think broadly. Include all segments in department. Use as many elements in department as you can to give students rounded education. It is heavily art and maker focused.
Program Management
Staff member works with recruiters to ensure student internships and careers options and advises students.
Change
You must plan for change. Plan so you can sustain program.
Curriculum Standards
Identify standards ACM and learning outcomes.
Community
Built connections with community. Staff work with recruiters to ensure student internships and careers options.
Evaluation
Make curriculum revisions at least 5-7 years.
Future
Plan for those who will succeed you.

Define and Ideate

These data provided a broad perspective of the field, types and names of programs, what the industry is looking for in graduates, and how other programs design and reformed curricular. The team reviewed data and identified the following opportunities for innovation. For each opportunity, an idea (Ideate) is provided directly below it.

1.*DMA Program purpose*. From interviews and brainstorming sessions, it appeared that a clear, shared mission or purpose statement was needed, as was clarity about terminology. Faculty had distinct perceptions about digital media and the DMA program's purpose. The following key goals were identified:

- Ensure DMA is (continues to be) one of the best programs of its kind
- Formulate (reaffirm) a common definition of who we are
- Define (re-articulate) the mission and goals of a DMA education
- Define (re-examine) what it means to be DMA graduate in terms of skills, knowledge, career paths
- Examine (re-formulate) the DMA curriculum in the context of our mission, goals, faculty strengths, industry trends, the academic milieu, and the characteristics envisioned for DMA graduates
- Maintain a viable curriculum that is coherent and reflects the industry and discipline

Ideate: Define a program mission that guides curriculum design and ensures that: a) curriculum serves the needs of students; b) students and faculty understand and share in the mission and character of the program; c) all courses relate directly to the mission; d) all curriculum changes and associated information materials derive from the mission; e) the curriculum appeals to designers, developers, and technologists and reflects industry practices.

2. *Greater alignment between program mission and industry "craft" skills and knowledge*. Students, faculty and industry partners expressed interest in ensuring that students understand and possess the "craft" skills and knowledge needed for professions in digital media and design.

Ideate: Form an advisory board to engage industry professionals and faculty to provide input about the curriculum and the DMA major.

3. *Categorization of course types*. From the interviews and brainstorming data, the team determined that over the years, in response to innovation, the objectives of the DMA concentrations evolved but the titles (Multimedia Development and Web Development) did not reflect this evolution. Both concentrations emphasize design (and related methodologies) with one concentration (Multimedia Development) focusing on visual information design and the other (Web Development) focusing on interaction design - using digital media to design interactive experiences that support human (users) tasks. Additionally, to attract student interests and convey the leading-edge character of the program, some course titles reflected technology innovation or software trends that in time become dated.

Ideate: To effectively communicate to our audiences, modify the names of the concentrations from Multimedia Development to Digital Media: Visual Communication and from Web Development to Digital Media: Human-Computer interaction. These titles were proposed by industry partners. When appropriate, add Studio (design studio, development studio, and video production studio) designation to course titles, to reflect the core nature of the subject rather than titles based on trends or software.

4. *Emphasis of digital media across concentrations*. From the analysis, while the concentrations emphasize design (visual and interaction design), there appeared to be a de-emphasis of media integration and classroom instruction highlighted mainly media topics specific to a

concentration. For example, the Web development concentration accentuated interactivity, databases, scripting or coding. Media formats and optimization were presented to a lesser degree and, when presented, they pertained to deploying interactive applications.

Ideate: Effectively integrate media (e.g., video, sound, animation, images) across concentrations. In introductory courses, ensure development of student proficiency in general digital media topics. Concentration courses should underscore specific digital media topics related to the student's concentration.

5. *Technical proficiency*. Students need adequate "craft" skills and knowledge before moving on to advanced courses. The analysis indicated a disparity of student technical skills and knowledge, which is problematic when students enter advanced courses.

Ideate: Establish a technical proficiency course that is designed by the faculty. The aims are to: 1) help students to become technically proficient in software (and hardware) operations; 2) normalize technical proficiency across all students; 3) potentially allow for increased class time (in all classes) to be devoted to higher-order learning about digital media theory, research and design – rather than software and hardware operation.

6. *Examine the current knowledge base*. The analysis highlighted that faculty members have diverse skills, training, and knowledge as well as different perceptions about digital media and the DMA program. While the diversity is valuable, the program must prepare students with a core foundation in digital media, design and development.

Ideate: Faculty must examine, articulate (to all faculty), and assimilate throughout the curriculum a base of concepts, theories, methods, literature, organizations, authors, innovators, etc. that serve as foundational knowledge in all courses (e.g., in other words, when students graduate, they must all be familiar with these authors, innovators, theories, methods, literature, standards, etc.).

7. *Program Evaluation*. There is a need for the DMA program to be evaluated every 3-7 years and core course to be evaluated yearly.

Ideate: Yearly: Faculty should meet to identify, review, and when necessary, revise competencies, goals, objectives, syllabi for each of the core courses. Every three to seven years: The entire curriculum and program should be examined on an ongoing basis at least every three to seven years. With the advisory board, establish measures and approaches by which to evaluate the curriculum and the program.

In this stage, the team created representations for a subset of ideas. Based on the work in the previous stages, the team proposed to rename the concentrations and to build multiple representations of the curriculum to test with the entire faculty and students. For the most part, these representations were formed around conceptual aspects. Processes and logistical issues were to be hopefully better identified in the testing phase, as constraints in this stage were prohibitive.

Program evaluation.

- Yearly: Faculty should meet to identify, review, and when necessary, revise competencies, goals, objectives, syllabi for each of the core courses.
- Every three years: The entire curriculum and program should be examined on an ongoing basis at least every three years. With the advisory board, we must establish measures and approaches by which to evaluate the curriculum and the program.

Possible approaches:

- Survey, collect feedback from graduates, students and parents
- Affiliations with industry and professional organizations – interview affiliates in the industry to ascertain trends and directions of the industry
- Compliance with Standards from the National Association of Schools of Art and Design Association of Computing Machinery
- Industry (advisory board) assessment of curriculum
- Identify innovations, startups, products created by students/graduates. Collaborate with regional businesses and organizations and educational institutions on design, technology, digital “new” media related projects. For example, industries and organizations in the region face pressing design-oriented problems for which they may lack resources or time to investigate or solve. These design-related problems are diverse and cross disciplinary.

Possible measures:

- Enrollment
- Number of new collaborations or relationships with industry
- Success of recent graduates (student accomplishments/innovations/startups, jobs, etc.)
- Faculty accomplishment (e.g., documentary awards, research, etc.)
- Student assessments or comments on instructors, courses, or curriculum.

Discussion

Adapting Design Thinking Processes

Figure 1 illustrates an adaptation of the DT framework. The team proceeded through each of design stage, a highly iterative process represented by the double-arrows throughout the figure. Because of its practice-based applied nature, the DMA program and ultimately the design existed in and needed to accommodate a dynamic and technologically innovative context or “reality”. For the program to be viable, it had to be responsive to the influences imposed on it by this context. External (e.g., changing technology, work processes, industry culture, innovations, etc.) as well as internal (e.g., departmental, college, university demands, etc.) factors exert continual influence on the program. The Influencing and Learning arrow in the upper left of figure 1 denotes how external sources serve as input or impose pressure and influence and provide opportunity for learning and improvement, assuming a design team has time and resources to effectively engage them - to help learn about professional and industry practices and ultimately enhance the curriculum. The academic program potentially influences, ideally in positive ways, external sources by preparing students to enter the profession, which is depicted by the Impacting or output arrow in figure 3.

Adapting the DT process, the team grouped individual stages into Reality and Artificial to distinguish between activities that a) facilitated engagement with "real-world" external influences or sources; and b) activities during which it had less engagement with external entities, but it formulated representations based on knowledge gained from them. The Reality group includes Empathize (renamed Strive to Understand) and Test. The Artificial group encompasses Define, Ideate and Prototype (renamed Form). In the Strive to Understand stage, members endeavored to understand the external "real" context or "reality" in which the program exists. The team used a variety of methods (e.g., interviews) to sample that reality to better understand it and to help formulate a program that adequately reflects it. This stage engaged the team in a real way with many external forces (e.g., industries, competing academic programs, etc.) that influence the program. In the Testing stage too, members engage with students who ultimately graduate and in turn potentially impact external sources. However, moving from Strive to Understand to the next three stages (Define, Ideate and Form), the team participated less with external entities, primarily because of limited time and human resources. In these stages (Define, Ideate and Form), members formulated representations (i.e., Artificial) based on what was understood from data collected in the Strive to Understand stage. In other words, the meanings, ideas, and prototypes created in Define, Ideate, and Form derived from information gather in Strive to Understand. At least initially, those representations were based on limited iteration and little or no input from external sources. As a result, an advisory board was formed to ensure design efforts aligned with external sources. In Figure 1, Representations-External Sources is included to denote the importance of aligning with external entities, as the team witnessed a general tendency to work less with external sources in these stages. Correspondingly, while members engaged less with external sources during Define, Ideate and Form, they observed increased attention on internal factors such as department issues, and instructor issues with courses. As show in Figure 2, the design team tended to focus on external influences during Strive to Understand and Test stages (Reality) and internal factors during Define, Ideate and Form (Artificial).

Two labels of the DT stages, Empathize and Prototype, did not fully reflect the scope of the design activities. The phrase Strive to Understand more so than Empathize captured the essence of the work at this stage. In many ways, team members were trying to understand the context and their own motives, as well as the factors that influence the program – rather than trying to empathize with a client, for example. When interviewing a person, the aim was not to glean information from the interviewee to design a solution to improve their life but rather the interviewee provided information to improve the academic program. Additionally, "strive" suggests ongoing processes. Through research, the team recognized the potential value of continual engagement with external influences, specifically professional industries, and how despite best efforts it can only obtain a sampling of their reality – and this heightened the need for further continuing engagement with such external entities.

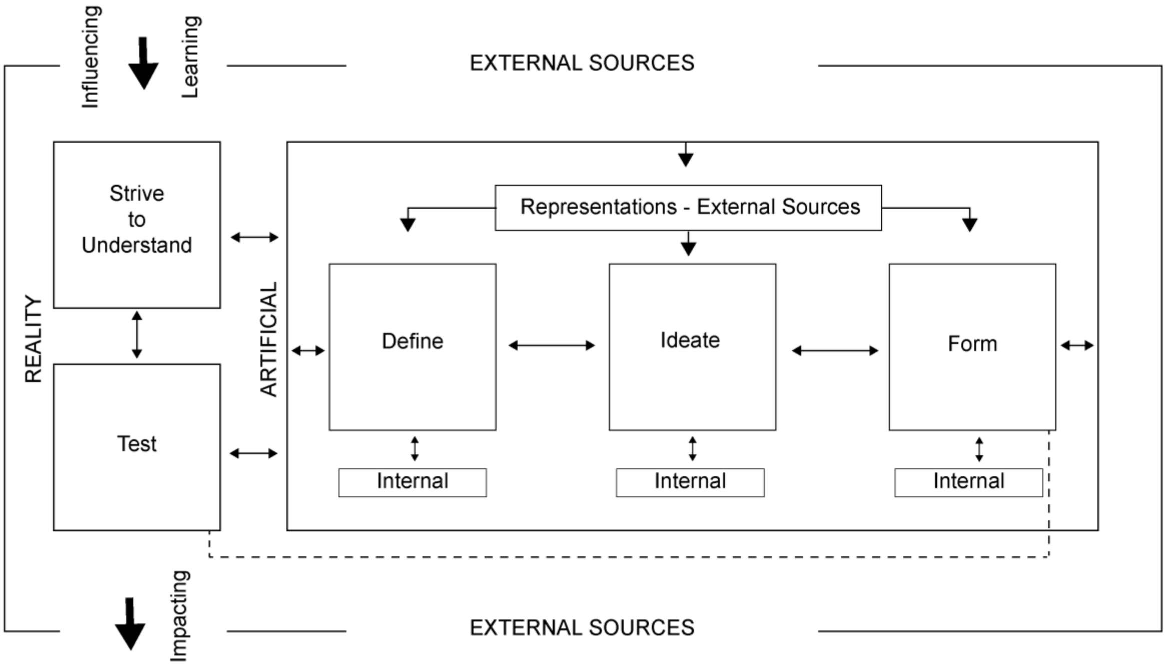

Figure 1: Adapted Design Thinking Process

Form rather than Prototype captured the essence of work at this stage. The nature of the design (a curriculum re-design) made it difficult to iterate designs in a sufficiently "real" context to reveal flaws or shortcomings. For instance, sharing prototype designs with users, yielded feedback largely focused on conceptual aspects (e.g., course topics and titles) versus process issues (e.g., course sequences, topic progressions). Moreover, curriculum changes often cause rippling effects on logistical and other unforeseen educational dimensions that could not be adequately identified. In terms of prototyping, an iterative process of design and user-testing that moves successively to more refined, higher fidelity close-to-finished products was largely true for conceptual facets but not so for process and logistical factors. Therefore, this stage consisted of forming conceptual representations of designs that, given the constrains, could only be evaluated during the Test stage. In Figure 3 there is direct connection between Form and Test, denoted by the dashed line, to indicate that these types of prototypes may require a higher degree of refinement or fidelity only achievable during the Test stage. Prototyping scenarios that afford a level of fidelity and rigor characteristic of traditional prototyping prior to the Test stage may be possible, but constraints proved prohibitive for this project.

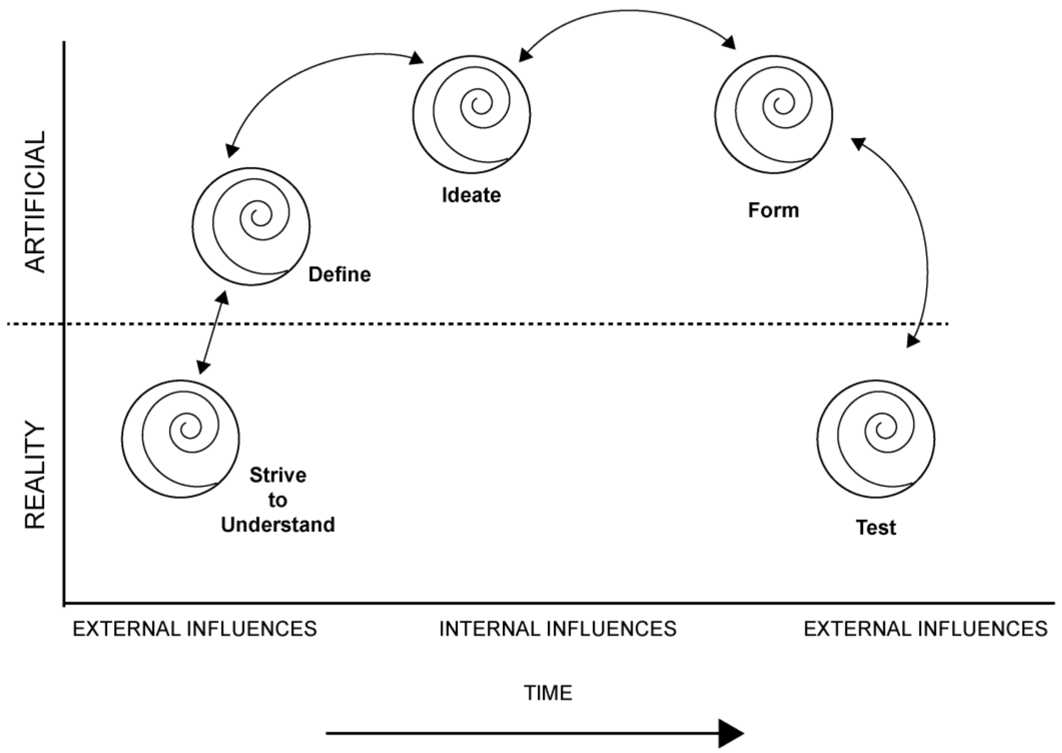

Figure 2: Design Thinking and Influences

Benefits and obstacles to using DT were observed.

Benefits

Given the unique challenges faced by digital media and technology-oriented programs, DT was a useful framework, particularly for non-designers, to structure program and curriculum assessment and re-design. It offered a frame of reference getting started. The program and curriculum work were multifaceted.

DT afforded a systemic view of problems. Iterations help engender thinking beyond the immediate team to external and internal sources to gain important insight about the feasibility of ideas and how they impact and would be impacted by the larger department and professionally community. It allowed the teams to understand the various epistemological frameworks that not only exited in the departments but also in the professional community. Initially, the team did not regard the professionally community (or members of) and the entire faculty as being part of the design team or one of its audiences, mainly to be sensitive to their time needs, which limited the perspective. Questions arose about who this work impacted and about our audiences, which eventually caused the team to be more inclusive.

Obstacles

It takes much time and work. Assessment and re-design are time consuming. Faculty members' time is limited by teaching, research and service and so their ability to engage in design activities is constrained. Introducing iteration throughout the DT process was unfamiliar to participants and, in some cases, they wanted to move on quickly after initial work was done.

There was also a tendency to be satisfied with initial findings and to stop further iteration or refinement.

It can be easy to overlook the impact of internal factors on design. It takes time for faculty to assimilate to a re-design of this type. The classroom environment is a uniquely individual experience for faculty, particularly those who excel at engendering connections with students. Pedagogical approaches, techniques to engage learners, imparting the classroom and departmental cultural, edifying the language of the discipline, among other things, are perfected over years of experience. A re-design of this type not only alters a curriculum structure, it re-forms the departmental cultural and classroom dynamics, the potential of which can be disorienting to faculty – and not readily apparent during the design process. Superficially applying a DT framework to a design is not likely to highlight such issues. At times the design team became excited about proposed changes, but it was important to ensure that those changes did not appear threatening to faculty. For instance, studio-based courses were proposed. For a faculty member who has taught successfully for years using lecture, demonstration, and discussion, restructuring a course to studio format can seem daunting. This is particularly germane for tenure-track faculty who might be concerned that making course format changes will impede student evaluations and their chances for tenure. It is important that all faculty, to the extent possible, partake in the design process – that they have input at each stage of the process so that they may take ownership of the design.

Terms such as empathy, iteration, and ideation helped to frame discussions and the overall work. At the same time, as team members learned about DT and its terms, the framework in its original form seemed highly suited for design problems in which a designer provides a design solution for an external client, where the solution directly benefits the client and not the designer. Conversely, as use here, the team served as designer and client and so the framework was modified somewhat (see figure 1).

Tools

DT provided a useful context in which to conduct the curriculum design. Tools that facilitate examining curricula are important components to design. Willness and Bruni-Bossio (2017) provide a useful framework, the Curriculum Innovation Canvas, that provides a logical structure to foster a creative and fluid approach to curriculum design. Major components include Stakeholder Groups, Stakeholder Relationships, Value Propositions, Activities, Resources, Constraints, Communications processes, Design-Content and Outcomes-Impact. Within each component, there are "…guiding questions to help the user identify and articulate their own content for each area." (p. 148). The authors note that the Canvas can be applied to a course, project, or entire curriculum. Designer may use Canvas to formulate curriculum ideas and examine them in unique ways.

Based on its work on the DMA curriculum, the design team adapted Canvas to use for future curriculum innovation (see Table 6). Major components in our adaptation are External Stakeholders, Internal Stakeholders, Proposed Value, Activities, Resources, Limits, Synergy, Content, and Outcomes. Because external factors have much impact on our curriculum, we included components for external and internal stakeholders. Stakeholder is a broad term that conveys the relationship of any person or entity engaged with or affected by the course or program (Willness & Bruni-Bossio, 2017). External stakeholders may be individuals at company, organizations or associations in the community. Internal stakeholders may be faculty, administrators, departments within the university.

Our adaptation of Canvas includes a prompt for definitions to clarify the language in describing courses and course concepts. Clarity about terminology helps reduce ambiguity, which is especially important for academic areas such as digital media where terms engender diverse meanings. In addition, based on data collected from interviews, we added prompts to reflect the scope (to include all personnel), existing standards (i.e., academic standard ACM), planning for change and preparation for future successors of the course or program. Moreover, the Curriculum Innovation Canvas includes components for activities, constraints, and resources. Our adaption presents prompts for activities, limitations, and resources in all major and minor components of the framework. For example, when thinking about external stakeholder relations, we wanted to provide prompts related to: a) the activities involved in establishing those relationships, b) limitations to achieving them, and c) resources needed to achieve them. At the same time, we thought it was useful to include these prompts - activities, limitations, and resources - in value statements, course content, and outcomes components. We used the term Limitations rather than Constraint to on focus on factors that might restrict the realization of a component.

In the context of the DMA curriculum, we envision our adaptation of Canvas could us foster reflection about establishing relationships with stakeholders, particularly external stakeholders, and maintaining synergy across stakeholders, courses, content, and learning outcomes. We think it could be used to help DMA, which is greatly influenced by external-professional forces (e.g., industry, technology innovation). Additionally, we could envision an electronic version of the framework that integrates Skills and knowledge data from Table 4, which would allow us to examine curriculum data in unique and diverse ways to gain greater insights and to aid in decision making.

Table 6. Adaption of Curriculum Innovation Canvas (Willness & Bruni-Bossio, 2017) to DMA Curriculum Design

Definitions
Define titles, descriptions used to describe course. Describe context in which language is used.
Is language relevant to social-cultural factors of program and larger professional community.
Scope, Standards, Change, Future
What is the scope of faculty, administrator and stakeholder involvement?
Are existing curriculum standards available? If so, what are they?
How will proposed course adapt to future changes-innovations? How can it be sustained?
How is course ready for future and those who will inherit it?
External Stakeholders
Define potential stakeholder who may be consulted.
Describe context (e.g., industry) in which stakeholder exist.
Describe how stakeholder can be involved (e.g., project-based learning, consultation, internships, service)?
Why is stakeholder important to course and program?
Describe stakeholder’s value or potential influence on program.
Describe benefits associated with establishing relationship that may advance student theoretical, methodological or technological understanding.
What activities must occur to established and maintained relationship? Who is responsible?

Describe resources (e.g., personnel, time, financial) needed to facilitate relationship.
What are limits on relationship (e.g., time, resources)?
Internal Stakeholders
Who should be consulted?
Describe context (e.g., faculty, administrator) in which stakeholder exist.
Describe stakeholder's relevance to course and program.
What activities must occur to established and maintained relationship? Who is responsible?
Describe resources (e.g., personnel, time, financial) needed to facilitate relationship.
What are limits on this relationship (e.g., time, resources)?
Synergy
Describe how synergy might be maintained among stakeholders, proposed course, and program.
What feedback and communications mechanism must be established?
What activities must occur for synergy to exist? Who is responsible?
Describe resources (e.g., personnel, time, financial) needed to facilitate synergy.
What limits synergy?
Proposed Value Statements
What value does the course add?
What value does course add to: students, program, internal and external stakeholder
Activities
Describe activities that must occur to fulfill the proposed value statement? Who is responsible (e.g., students, internal stakeholders, external stakeholders)?
Describe resources (e.g., personnel, time, financial) needed to facilitate value statement.
What are limits on this activity (e.g., time, resources) to fulfilling value statement?
Content
Major course topics and how they align with value statement(s).
How are major course topics associated and aligned with internal and external stakeholders?
Describe course activities aimed to fulfill each value statement.
Describe resources needed to facilitate course topics.
Are there limits related to executing the course topic (e.g., time, resources)?
Outcomes
What are desired student learning outcomes? What indicators provide evidence? How will you measure success?
What are desired outcomes for program, internal and external stakeholders?
Describe activities that must occur to fulfill outcomes.
Describe resources needed to facilitate outcomes.
Are there limits related to fulfilling outcomes?

Summary

Academic programs in digital media face unique challenges. Digitization and corresponding digitalization, while spurring innovation and emergent technologies, disrupt business and educational institutions as they must continually adapt to rapid innovation to keep pace. These forces instigate a new order of challenges, often highly complex and ill-defined. As used in this project, a DT framework can provide, with modification, a ready and easily interpreted framework for non-designers to structure and guide curriculum design.

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27.2

Mapping current research and future directions of Design Literacy with systematic quantitative literature review (SQLR)

Julius Cesar Bolinas, Griffith University, Australia

Abstract

Design literacy is an emerging research field that is gaining attention among scholars today. Credit goes to the growing acceptance of design thinking in various disciplines beyond design. Design literacy develops natural abilities in everyone to solve real-world, wicked problems by supporting the cognitive development of concrete (making things) and iconic (making meanings) modes of cognition. The author argues for embedding design literacy in every educational level, particularly across disciplines in higher education. To gain insight into the state of scholarly discourse around design literacy in educational contexts, a systematic quantitative literature review (SQLR) was conducted using 12 databases to map its research direction and define its characteristics. The SQLR revealed several findings. First, the foundations of design literacy are grounded in general education and design education. Second, publications were meagre but well represented by the secondary and higher education level. Finally, two thematic directions were observed - *design literacy for making things* is the situated practice in secondary education while *design literacy for making meanings* is for higher education. This SQLR serves as a benchmark review and a starting point to initiate scholarly discourse on design literacy as it aims to contribute to the advancement of research in the field.

Keywords

design literacy, digital learning, participatory culture, systematic quantitative literature review (SQLR), making things, making meanings

Introduction

Digital technology enabled learning and select human activities to move online, especially in pandemic times. However, not everyone was prepared with requisite skills and mindset to manage the digital shift. The move to digital learning and engagement requires new ways of learning or literacy to participate effectively in the digital environment (Lankshear & Knobel, 2007). There are many kinds of literacy that emerged in the information age (Leu et al., 2015) but design literacy is argued by the author as more appropriate to facilitate this transition.

Design literacy is a relatively new term and defining it is challenging and contentious. There is a caveat to this attempt whilst a definition of some kind may emerge from the literature itself. To give context to the term 'design literacy', design as a word and a discipline is defined subsequently. It is used as a noun and a verb to refer to the product or the process of making (Balsamo, 2009). Design is embodied in the artefact in its operation and practice (Jones, 2014). Design as a discipline is the third pillar of knowledge after the sciences and the humanities (Archer, 1979; Cross, 1982). Design exemplifies the practice of *learning by doing* (Archer, 1979; Pacione, 2010; Poggenpohl, 2008; Sheridan & Rowsell, 2010) which is what people do as they rework materials and meanings to adapt their needs around the growing ubiquity of digital technology. Design is inherently anthropocentric (Archer, 1979) or human centred (Burdick & Willis, 2011; Pacione, 2010). Design's intrinsic ability to put people's wellbeing and interest at the core of what Margaret Mead (1978) refers to as a *radical cultural change* or digital revolution makes design an appropriate platform to support the emergence of a literacy that is learner centred (Jones, 2014) inside the digital environment. Furthermore, the acceptance of design thinking (Bower, 2017; Brown, 2008; Donaldson & Smith, 2017; Razzouk & Shute, 2012) as a creative tool of inquiry in problem solving is now applied to other fields beyond the practice of design (Adikari et al., 2013; Dunne & Martin, 2006; Liedtka, 2014; Thi-Huyen et al., 2021). It elevated the application of design's intrinsic qualities to address the emerging concerns of digital learning (Jones et al., 2021; Lotz et al., 2018; Marshalsey & Sclater, 2020) and engagement in the knowledge economy that it fostered.

Design Literacy Defined

Liv Merete Nielsen and Karen Brænne (2013) defines design literacy as the competence of communicating meaning, function and quality to empower anyone using multiple modes of knowledge to produce material culture. Eva Lutnaes (2020) extends this concept to advocate for changes to Years 1-10 curriculum to introduce and advance socioecological sustainability awareness in design education. Their context of design literacy is situated in secondary and primary education respectively. On the other hand, design literacy for Chris Pacione (2010, 2017), are the skills in inquiry and observation, evaluation and synthesis to solve complex problems with design not only in the physical world but also in the digital environment. He situates design literacy within the context of higher education and beyond. It is important to stress that their concept of design literacy is for everyone, especially those coming from non-design backgrounds. Design literacy is not for those who are studying to become professional designers as they already have the design faculties and have acquired the design fluency to practice design as a profession. Design literacy is envisioned by the author as a model of design education to introduce and institutionalize the designerly ways of knowing (Cross, 1982), designerly ways of thinking (Pacione, 2010) and designerly stance to inquiry (Christensen et al., 2016) in general education, especially for non-design disciplines in higher education.

Designerly way of knowing according to Nigel Cross (1982) is the ability to: a) identify the wicked nature of real-world problems, b) use solution-focused approach to solve these problems, c) use design thinking (aka constructive or abductive thinking) in generating solutions, d) transform abstract ideas to concrete *objects* (or solutions) through the process of *making*, and e) apply the skill of *making objects* to *making meanings* (read and write in object languages) to make sense of the process. Cross argues for the justification of design in general education as: a) design develops natural abilities to solve complex, real-world problems, b) design supports cognitive functions in the *making of things* (concretizing modes) to *making of meanings* (iconic modes) and, c) design supports the development of non-verbal thoughts and communication or *tacit knowledge*. These are the aims of design as a literacy for everyone.

Designerly ways of thinking according to Pacione (2010) is using *Look-Understand-Make* process (*Praxis of Design Thinking)* to understand problematic situations. *Look* is the process of using inquiry and evaluation to gain empathy or informed perspective to build insight on a problem. *Make* is the process of forming and concretizing solutions in a series of experimentation. In between these steps is *Understand* or the process of *making sense of things* or *making meanings* as one improves on a solution from previous iterations.

Designerly stance to inquiry according to Kasper Skov Christensen et al. (2016) is an important part of design literacy. It is the precondition for initiating design thinking process in a problematic situation. The current education system is designed to produce routine experts among graduates. Routine experts see real-world problems as tame and well-defined. However, real world problems are wicked in nature. By developing the students' designerly stance to inquiry (aka reflective inquiry), design literacy prepares them to take on real-world problems with an empathic, investigative, and inquisitive approach in problem-solving.

Design literacy in the context of this study is the competency to develop skills in *making things* (concretizing mode) and *making meanings* (iconic mode) using designerly ways of knowing, thinking, and inquiring. These learning dispositions are crucial to develop tacit knowledge that is essential in today's knowledge economy. The knowledge economy is built on knowledge intensive activities requiring high-level skills and tacit knowledge, or the skills in implementing codified knowledge (Pettinger, 2017; Polanyi, 1962). Tacit knowledge comes from learning-by-doing and is the signature pedagogy of design (Crowther, 2013; Poggenpohl, 2008).

The digital environment is a place that supports learning-by-doing and prepares students for a world that relies increasingly on digital technologies. Inside this digital space, they design with materials both physical and virtual using multimodal forms of text such as images, audio, video or interactive content (Apperley & Beavis, 2013; Cazden et al., 1996; Victoria-State-Government, 2022). These variegated elements support non-linear communication and opens new forms of *meaning making* using different medium (SMS, emails, wikis, blogs, vlogs, etc), various formats (JPEG, PNG, GIF, PDF, SVG, MP4, etc) and diverse social media (Tiktok, Snapchat, Instagram, Youtube, Facebook, etc.).

Design literacy develops the students' learning dispositions that support their engagement inside the digital environment. Digital engagement is unconstrained by time nor distance, virtual and networked, with its own social norms embodied in participatory culture (Jenkins, 2009). Participatory culture is a phenomenon in the digital environment where experienced participants pass knowledge to novices as they create and share digital culture. It recalls to mind the mentor-apprenticeship relationship of traditional design studios (Poggenpohl, 2008). Design as a convergent medium has the facility and agency of supporting meaning making in the consumption, production, and distribution of digital culture in communities of practice like participatory culture. As students engage with digital media, they produce digital culture and foster learning and engagement inside the digital environment. The author reaffirms the nuanced role of meaning-making that design literacy engenders. This observation is shared with scholars in the field (cf. Kalantzis & Cope, 2018; Sheridan & Rowsell, 2010).

Research Stimulus

In 2012, the European Design Leadership Board (EDLB) of the European Union released directive #20 which recommends "to raise the level of design literacy for all the citizens of Europe by fostering a culture of *design learning for all* at every level of the education system" and #21 to "support the development of design competencies for the 21st century by embedding the strategic role of *design across disciplines in higher education*" (Thomson & Koskinen, 2012, p. 73) (emphasis supplied). This highlights the need for design literacy in all levels of education and across disciplines in higher education. This directive is the needed stimulus for design literacy to prosper, particularly in its emphasis on higher education.

Why a systematic quantitative literature review (SQLR)?

A scoping exploration of literature around design literacy revealed an apparent absence of SQLR. Hence, the aims of this article are a) to map the breadth of literature on design literacy as a benchmark review by using SQLR, b) to establish baseline information and track the use of 'design literacy' in general education, particularly in higher education, and c) to test if SQLR is an appropriate method of inquiry than narrative review to identify themes, directions, or capture characteristics of design literacy as an emerging research topic.

A narrative review relies on the credibility of the reviewer's expertise on the topic and may oftentimes be open to reviewer's biases. In the absence of topical expertise of early career researchers or veteran researchers working on a new topic, SQLR provides an alternative means of gathering relevant information for building new knowledge on a research topic. It requires entry level skills of quantifying information based on a specific set of criteria and systematic review of databases. In summary, SQLR relies on objective, transparent criteria to allow reproducibility of results (Collins & Fauser, 2005; Cook et al., 1997; Pickering & Byrne, 2014).

Research Direction Amendment

Two questions were raised at the start of the search: a) What is the state of design literacy and its significance in higher education? and b) Will SQLR be a viable mode of inquiry to review literature of this emerging research topic? A scan of literature during the initial scoping review uncovered two results: a) the meagre quantity of design literacy research on higher education, and b) the availability of research on secondary and primary education, and the educators in these sectors as well as purely conceptual frameworks with no participants in the study. The author's research direction thereafter was amended to capture instead a bigger picture of design literacy's development in general education to inform the author's interest in higher education. This strategic decision is important because higher education provides the leadership in curricular changes in response to societal transformations and market demands (Wright et al., 2013). The primary and secondary education, and the industry, move in line with higher education's initiatives. An internationally competitive higher education system sustains the high standards of living in a country like Australia where international education is its fourth largest export, generating $40.3 billion income in 2019, with approximately 70% ($27.8 billion) is attributed to higher education sector's contribution (Universities-Australia, 2020, p. 42) to their economy.

Research Findings

Midway through the review, the advantages of employing SQLR became apparent over narrative review: a) the agency it provides to arrive at a quantifiable and reproducible result for others to undertake, and b) its suitability for "emerging areas and for areas where methodical approaches are so diverse that there is limited potential for other types of quantitative reviews such as meta-analysis" (Pickering & Byrne, 2014, p. 539). By employing SQLR, the author was able to identify three major findings. First, design literacy originates from two distinct discipline: General education represented predominantly by the secondary education sector, and Design education. Second, design literacy is defined by its situated practices: in general education, it is *Design Literacy for Non-designers* (DLN) while in design education, it is *Design*

Literacy for Designers (DLD). Finally, under DLN's scope, two emergent themes were identified: *design literacy for making things* define design literacy in secondary education while *design literacy for making meanings* define design literacy in higher education. The implications of these findings are discussed in the *Results* and *Discussion* section.

Methodology

Databases and search phrase

A systematic, quantitative literature review (SQLR) was conducted using twelve databases namely, Google Scholar, ProQuest, Griffith Library Catalogue, SpringerLINK, JSTOR, Web of Science, Taylor and Francis, SAGE, Scopus, ERIC, Design and Applied Arts Index, and Bloomsbury Design Library. The search phrase used was ("design literacy") AND ("higher education" OR HE OR tertiary OR "university students") for all databases except for Web of Science where the search term used was "design literacy" because the complete search phrase generated no result. All databases except Bloomsbury Design Library produced results. These results were refined using the filters *last 10 years, peer reviewed,* and *journal article* found in each database. The number of journal articles came down to 225 after the refinements. Furthermore, the number of journal articles were reduced to 41 after reviewing the title and abstract. Refer to Table 1: Database Search Result for details. Refer to Appendix A for complete results of Database Search.

Table 1: Database Search Result

Resource	Search Terms	Refinements	Papers used
Google scholar	("design literacy") AND ("higher education" OR HE OR tertiary OR "university students")	Last 10 years - 1210 Peer reviewed - 22 Journal article - 22	16
ProQuest	("design literacy") AND ("higher education" OR HE OR tertiary OR "university students")	Last 10 years - 361 Peer reviewed - 52 Journal article - 52	6
Griffith Library Database	("design literacy") AND ("higher education" OR HE OR tertiary OR "university students")	Last 10 years - 137 Peer reviewed - 68 Journal article - 66	8
SpringerLink	("design literacy") AND ("higher education" OR HE OR tertiary OR "university students")	Last 10 years - 109 Peer reviewed - 18 Journal article - 18	1
JSTOR	("design literacy") AND ("higher education" OR HE OR tertiary OR "university students")	Last 10 years - 27 Peer reviewed - 24 Journal article - 17	1
Web of Science	("design literacy")	Last 10 years - 29 Peer reviewed - 18 Journal article - 18	2
Design and Applied Arts Index (DAAI)	("design literacy") AND ("higher education" OR HE OR tertiary OR "university students")	Last 10 years - 15 Peer reviewed - 12 Journal article - 12	2

Taylor and Francis	("design literacy") AND ("higher education" OR HE OR tertiary OR “university students”)	Last 10 years - 12 Peer reviewed - 12 Journal article - 12	2
SAGE	("design literacy") AND ("higher education" OR HE OR tertiary OR “university students”)	Last 10 years - 6 Peer reviewed - 6 Journal article - 6	1
Scopus	("design literacy") AND ("higher education" OR HE OR tertiary OR “university students”)	Last 10 years - 3 Peer reviewed - 1 Journal article - 1	1
ERIC	("design literacy") AND ("higher education" OR HE OR tertiary OR “university students”)	Last 10 years - 1 Peer reviewed - 1 Journal article - 1	1
Bloomsbury Design Library	("design literacy") AND ("higher education" OR HE OR tertiary OR “university students”)	Last 10 years - 0 Peer reviewed - 0 Journal article - 0	0
Total		Journal articles - 225	41

The articles covering secondary and primary education were part of the research set produced from the search. During the initial scoping review, the author re-assessed the research direction after finding only a few journal articles on higher education was available. By including journal articles that discussed other cohorts like secondary and primary education, the systematic search became more inclusive and descriptive of design literacy’s situated practices in the whole education spectrum.

Selection criteria

The inclusion criteria were: 1) original, peer-reviewed English journal articles with *design literacy* in its title, abstract, or body of literature, 2) journal articles that have specific student cohorts in their studies i.e., in primary, secondary or higher education, or the educators in these cohorts, or 3) journal articles that discussed conceptual framework or experts’ opinion pieces about design literacy without student cohorts, and 4) journal articles that discuss design literacy as part of general education. All journal articles were reviewed and further screened by removing 1) book chapters, conference proceedings or theses, etc otherwise known as *grey literature*, 2) journal articles where *design* was used as a verb *to design* literacy instead of the noun, *design literacy*, 3) journal articles where *design literacy* was only found in the bibliography or references, 4) journal articles that used design literacy incorrectly as a term referring to other meaning like *orientation* or *communication*, and 5) journal articles that have very specific type of literacy like *game design literacy*. Journal articles were considered if they use more complex phrases like *digital design literacy* or *critical digital design literacy*, or a term that is synonymous like *aesthetic knowledge*.

Table 2 Inclusion Criteria, Exclusion Criteria and Exemptions

Inclusion Criteria
1. Peer-reviewed English journal articles with *design literacy* in its title, abstract or body of literature
2. Journal articles with student cohorts i.e., primary, secondary, or higher education, or its educators

3. Journal articles that discuss conceptual framework or experts' opinion pieces about design literacy
4. Journal articles that discuss design literacy as part of general education
5. Journal articles that were published from 1 January 2010 to 15 December 2020
Exclusion Criteria
1. Book chapters, conference proceedings, theses, etc. otherwise referred to as *grey literature*
2. Journal articles where *design* was used as a verb *to design* literacy
3. Journal articles where design literacy was only found in the bibliography or reference section
4. Journal articles that used *design literacy* differently to refer to another meaning like orientation, etc
5. Journal articles that have very specific type of literacy like *game design literacy*
Exceptions
1. Journal articles using complex phrases like *digital design literacy* or *critical digital design literacy*
2. Journal articles that uses synonymous term like *aesthetic knowledge*

The journal articles were collected from 13-15 December 2020. Publications included in the search were from 1 January 2010 to 15 December 2020. Journal articles before or beyond the inclusive dates were not included in the review. In total, 41 journal articles were eligible for review after passing through the selection criteria. The literature search was limited to three days as algorithm of search engines change periodically without warning. The 41 journal articles were reviewed and completed in January 2021. There were 25 journal articles excluded from the second review in February 2021 leaving only 16 journal articles for the final SQLR review.

SQLR Flowchart

The method of selection used the *preferred reporting items for systematic reviews and meta-analyses* (PRISMA) (Moher et al., 2010) flowchart in Figure 1: SQLR Methodology Flowchart. The flowchart has 4 stages namely, *Identification, Screening, Eligibility* and *Included*. Under the *Identification* stage, the search phrase ("design literacy") AND ("higher education" OR HE OR tertiary OR "university students") was used in all database search except for Web of Science where ("design literacy") sufficed. Records identified through the database search were added to records that were identified by the author from other sources. In the *Screening* stage, all records were screened for duplicates leaving 246 journal articles to go through screening by title and abstract. The 225 journal articles that passed through this screening underwent further review by removing journal articles outside the inclusive dates, grey literature, not written in English, citations only, or full text was not available from regular online research. There were 41 full-text journal articles that reached the *Eligibility* stage but 25 of these were excluded based on listed criteria. In total, 16 journal articles were eligible for review for quantitative synthesis in the *Included* stage.

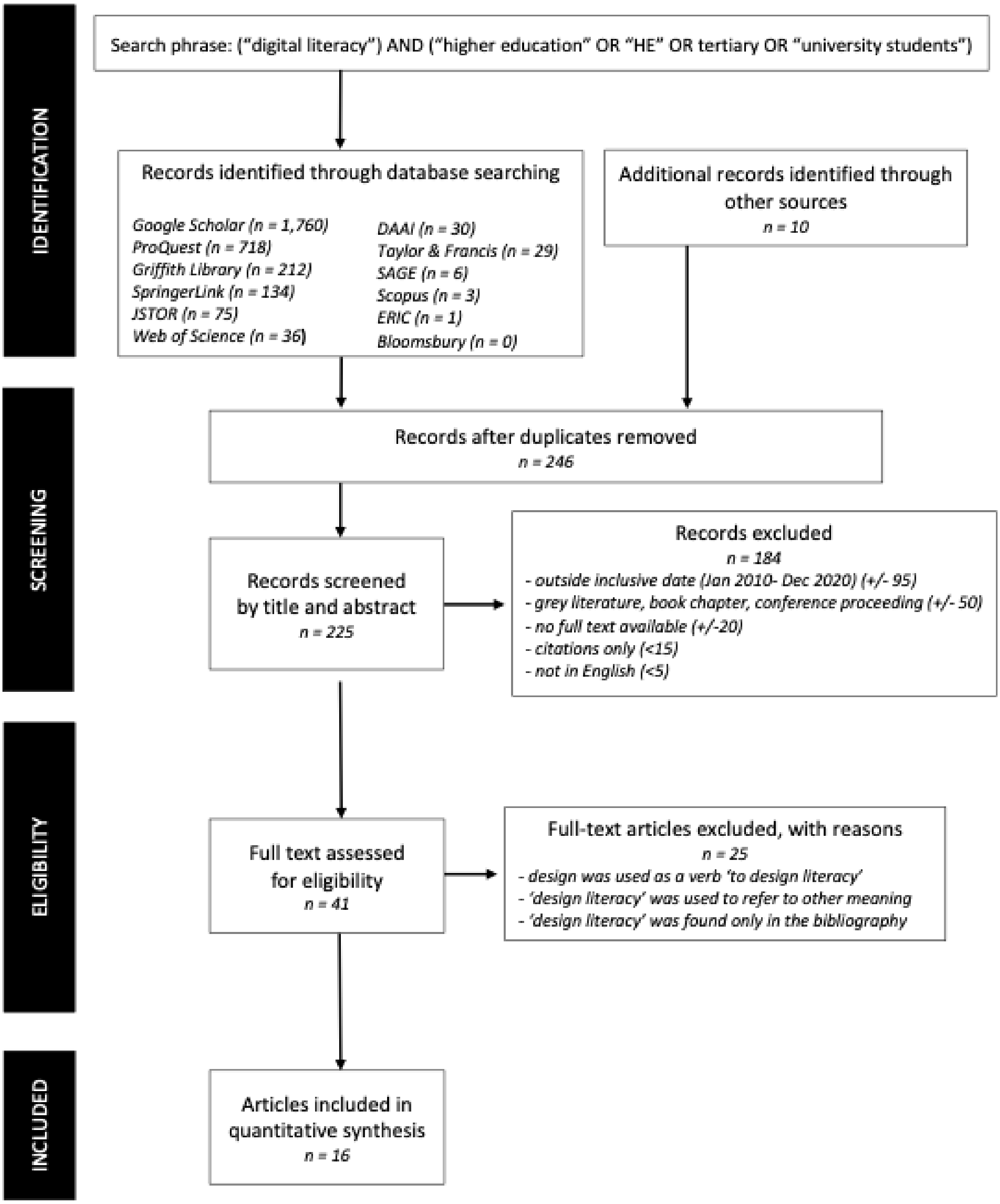

Figure 1: SQLR Methodology Flowchart

Results

The SQLR was conducted to gain better understanding of the state of design literacy research by identifying thematic directions and emergent gaps. The 16 journal articles gleaned from the 12 databases were encoded in Excel spreadsheet using relevant Pickering systematic reading criteria (Pickering, 2021) based from their seminal journal article on SQLR (Pickering & Byrne, 2014). The findings were tabulated under the categories *Publication Year, Country of Origin /*

Publication, Disciplinary Field and Type of Design Literacy, Broad Topics, Specific Topics, Research Methodology, and *Emergent Themes*. New categories were added or expanded during the review process. For example, a new category *Sector* was added to represent the primary, secondary and higher education levels. It was later expanded to include new categories like *Educator* and *Concepts* to accommodate new findings from some journal articles that do not cover student as subjects in the study but discusses capacity building among educators, or conceptual frameworks on design literacy. The decision to place the 16 articles as columns was strategic because they remained constant throughout the review. The variables were placed in rows to make addition or revision more manageable during the review process. Affixing '1' as value for each identified category resulted to quantifiable data after all the information were listed in the table. Refer to Table 3: Table of Results.

Table 3: Most frequent is highlighted and in bold letters

CATEGORIES	DETAILS	SELECTED ARTICLES																TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
		Ehret et al.	Gravel et al.	Haag & Marsden	Lim et al.	Yorgancioglu &	Christensen et al.	Christensen et al.	Maus	Maus	Rahimi et al.	Lerner	Lutnaes	Nielsen & Braenne	Pacione	Pangrazio	Wright et al.	
Publication Year	2020					1							1					2
	2019								1	1								2
	2018	**1**		**1**				**1**			**1**	**1**					**1**	**6**
	2017		1															1
	2016						1									1		2
	2013													1				1
	2011				1													1
	2010														1			1
Country of Origin / Publication	Australia															1	1	2
	Canada										1							1
	Denmark						1	1										2
	Germany			1														1
	Norway								**1**	**1**			**1**	**1**				**4**
	South Korea				1													1
	Turkey					1												1
	USA	**1**	**1**									**1**			**1**			**4**
Disciplinary Field and Type of Design Literacy	**Design (Design literacy for Designers)**																	5
	Architecture					1												1
	Industrial Design				1													1
	Art & Design											1		1	1			3
	Education (Design literacy for Non-Designers)																	**11**
	General education	1											1			1		3
	Secondary education						**1**	**1**	**1**	**1**	**1**						**1**	**6**
	STEM education		1	1														2
Broad Topics	Affect and participatory culture	1																1
	Maker spaces literacy		1															1
	Empathy			1														1
	Interaction design				1													1
	Design education					1												1
	Designerly stance towards inquiry						1	1										2
	Design literacy for sustainability								1	1				1				3
	Visual-spatial skill and Design literacy											1						1
	Design literacy for primary level												1					1
	Design literacy for secondary level						**1**	**1**	**1**	**1**	**1**		**1**	**1**				**7**
	Design literacy for all														1	1		2
	Design literacy as production of digital artifacts															1		1
	Design literacy for educators																1	1
Specific Topics	Booktubers	1																1
	STEM literacies in maker spaces		1															1
	Use of persona in user-centred design			1														1
	Somaesthetics				1													1
	Critique and its role in design literacy					1												1
	Design literacy tool (DeL)						1											1
	Fablab							1										1
	Case Keramikk								1									1
	Case Sveip (bentwood box)									1								1
	Interest-driven literacy										1							1
	Visual-spatial ability and problem-solving skill											1						1
	Responsible design literacy												1					1
	Design for longer-lasting products													1				1
	Design literacy for non-designers														1			1
	Critical digital literacy to digital design literacy															1		1
	Design immersion program for educators																1	1
Research Methodology	Case Study	1	1	1	1	1	1	1	1	1	1							10
	Interview / Focus Group	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**						**1**	**11**
	Narrative / Literature Review											1	1	1	1	1	1	6
Sector	Tertiary	1	1	1	1	1												5
	Secondary						**1**	**1**	**1**	**1**	**1**		**1**				**1**	**7**
	Primary												1					1
	Educators										1						1	2
	Concepts											1		1	1	1		4
Emergent Themes	**Design literacy for *making things* in physical world**		**1**			**1**	**1**	**1**	**1**	**1**			**1**	**1**			**1**	**9**
	Design literacy for *making meanings* in digital environment	1		1							1				1	1		5
	Both				1													1
	Neither											1						1

Authors and Journal Articles

The most cited article from the SQLR was Pacione's (2010) with five authors in the SQLR citing his article. Nielsen & Brænne (2013) and Christensen et al. (2016) came second with three citations each. Refer to Table 4: Author by Author Citation.

Table 4: Most frequent is highlighted and in bold letters

AUTHORS	YEAR	SELECTED ARTICLES															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Ehret et al.	Gravel et al.	Haag & Marsden	Lim et al.	Yorganciolgu & Tunali	**Christensen et al. 2016**	Christensen et al. 2018	Maus 2019a	Maus 2019b	Rahimi et al.	Lerner	Lutnaes	**Nielsen & Braenne**	**Pacione**	Pangrazio	Wright et al.
Ehret et al.	2018																
Gravel et al.	2017																
Haag & Marsden	2018																
Lim et al.	2011																
Yorganciolgu & Tunali	2020						1								1		
Christensen et al.	2016														1		
Christensen et al.	2018														1		
Maus	2019a						1			1				1	1		
Maus	2019b								1					1			
Rahimi et al.	2018																
Lerner	2018																
Lutnaes	2020						1	1			1	1		1	1		
Nielsen & Braenne	2013																
Pacione	2010																
Pagrazio	2016																
Wright et al.	2018																
TOTAL							**3**	**1**	**1**	**1**		**1**		**3**	**5**		

The author considers Pacione's article as a landmark article for the following reasons: a) this is where *design literacy* was clearly declared as a literacy for everyone and positions design as the human-centred literacy for the digital age, b) Pacione argues that what arithmetic has done to the industrial age, design literacy can do for the digital age and the knowledge economy, and c) its publication year (2010) has influenced the author's decision to scope this SQLR to a decade (2010-2020) of peer-reviewed articles after its publication year. The European Design Leadership Board released its design directive two years after Pacione's publication, reflecting these milestones of design literacy within the inclusive dates identified.

Publication Year

The highest number of publications in a year happened in 2018 with 6 journal articles from 5 countries: USA (2), Australia, Canada, Denmark, and Germany. There were two publications in 2020, 2019 and 2011 while the rest of the years have one journal article published except in 2015, 2014 and 2012. The SQLR showed design literacy publications peaked in 2018 and had maintained momentum onwards. It indicates the interest on the topic is steady if not on an increasing trend.

Country of Origin / Publication

The inclusion of *Country* as a category of interest is to highlight the origin of research and publication trend in this area. Location may be a factor in influencing conceptual development or dissemination of trends in design literacy. There were 8 countries where the journal articles were published. Norway and the USA each have four publications. Denmark and Australia each have two published articles. Countries with single publication are Canada, Germany, South Korea and Turkey. Results show that European countries like Norway and Denmark have the most publications on design literacy and this can be attributed to the European Design Leadership Board's (EDLB) design directive to promote *design learning for all* at all levels of education and *across disciplines in higher education*. This is further discussed in the *Discussion* section.

Disciplinary Field and Type of Design Literacy

The disciplines of Design and Education are the two broad areas where design literacy research originates. The Design discipline has a total of 5 articles represented by the fields of Art & Design education (3), Architecture (1) and Industrial Design (1). The author refers to this cohort as *Design Literacy for Designers (DLD)*. The Education discipline has 11 articles represented by secondary education (6), general education (3) and STEM education (2). The author refers to this cohort as *Design Literacy for Non-Designers (DLN)*. This finding positively illustrates the bifurcation of origin and development of design literacy in the Design and Education disciplines respectively. Refer to Table 5: Field and Type for details.

Table 5: Most frequent is highlighted and in bold letters

CATEGORIES	DETAILS	SELECTED ARTICLES																TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
		Ehret et al.	Gravel et al.	Haag & Marsden	Lim et al.	Yorganciogl u &	Christensen et al.	Christensen et al.	Maus	Maus	Rahimi et al.	Lerner	Lutnaes	Nielsen & Braenne	Pacione	Pangrazio	Wright et al.	
Disciplinary Field and Type of Design Literacy	Design (Design literacy for Designers) (DLD)																	5
	Architecture					1												1
	Industrial Design				1													1
	Art & Design											1		1	1			3
	Education (Design literacy for Non-Designers) (DLN)																	**11**
	General education	1											1			1		3
	Secondary education						**1**	**1**	**1**	**1**	**1**						**1**	6
	STEM education		1	1														2

A curious question arouse why design literacy is found in Education, particularly why the Education discipline has the most journals on design literacy. A retrospective view explains why: Design literacy's emergence was supported by an earlier type of literacy enabled by digital technologies referred to as 'digital literacy'. Digital literacy was used as a term to mark the move of information sciences or library resources to the digital era (Bawden, 2001). The advocates of digital literacy mostly came from the fields of learning and literacy which are the domains of the Education and English department, and to some extent*,* Technology. Burdick and Willis (2011) states that these disciplines also refer to digital literacy as *multimedia literacy*. They cited literacy advocates like the *Partnership for 21st Century Skills*, *EDUCAUSE*, and *New Media Consortium*, quoting the latter's definition of 21st century literacy as "the set of abilities and skills where aural, visual, and digital literacy overlap. This includes the ability to understand the power of images and sounds, to recognize and use that power, to manipulate and transform digital media, to distribute them pervasively, and to easily adapt them to new forms" (New-Media-Consortium, 2005, p. 2) . Burdick and Willis (2011) argue that in many ways, the 21st century literacy they advocate is very much like designing. Burdick and Willis further suggest that the combined skills of designerly ways of knowing (Cross, 1982), and the specialised fields of communication, interface design, and interaction design, provide the vital link to shift the study of multimedia literacy to the field of design. This observation brings to light design's connection to learning in the digital domain. Consequently, the foremost finding from the SQLR confirms Education and Design as the disciplines where the design literacy articles originated. This will be discussed further under *Emergent Themes*.

Broad and Specific Topics

There were 13 broad topics that branched to 16 specific topics from the journal articles in review. Seven journal articles discussed more than one topic on the list. The most discussed topic was design literacy for sustainability focusing on secondary education curriculum. This will be discussed further in the *Discussion* section. The broad and specific topics were summarized from reviewing all 16 articles' *Abstract* and content. They were easily identified from the articles' narrative. The identification of specific topics took several evaluation processes involving the author and principal supervisor to prevent reviewers' bias particularly if an article covers several topics. Both came to agreement that the topic that was heavily discussed in each article was declared the *Specific Topic* and the final list appears on Table 3. For clarity, Table 6: Broad and Specific Topics is shown:

Table 6: Most frequent is highlighted and in bold letters

CATEGORIES	DETAILS	SELECTED ARTICLES																TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
		Ehret et al.	Gravel et al.	Haag & Marsden	Lim et al.	Yorganciolglu &	Christensen et al.	Christensen et al.	Maus	Maus	Rahimi et al.	Lerner	Lutnaes	Nielsen & Braenne	Pacione	Pangrazio	Wright et al.	
Broad Topics	Affect and participatory culture	1																1
	Maker spaces literacy		1															1
	Empathy			1														1
	Interaction design				1													1
	Design education					1												1
	Designerly stance towards inquiry						1	1										2
	Design literacy for sustainability								1	1				1				3
	Visual-spatial skill and Design literacy											1						1
	Design literacy for primary level												1					1
	Design literacy for secondary level						**1**	**1**	**1**	**1**	**1**		**1**	**1**				**7**
	Design literacy for all														1	1		2
	Design literacy as production of digital artifacts															1		1
	Design literacy for educators																1	1
Specific Topics	Booktubers	1																1
	STEM literacies in maker spaces		1															1
	Use of persona in user-centred design			1														1
	Somaesthetics				1													1
	Critique and its role in design literacy					1												1
	Design literacy tool (DeL)						1											1
	Fablab							1										1
	Case Keramikk								1									1
	Case Sveip (bentwood box)									1								1
	Interest-driven literacy										1							1
	Visual-spatial ability and problem-solving skill											1						1
	Responsible design literacy												1					1
	Design for longer-lasting products													1				1
	Design literacy for non-designers														1			1
	Critical digital literacy to digital design literacy															1		1
	Design immersion program for educators																1	1

Research Methodology

Focused group interview was the most popular method used from the selected journal articles. It was closely followed by case studies. The rest of the articles featured narrative review in combination with review of literature for articles discussing conceptual frameworks.

Sector

The most researched sector was the secondary education sector with seven articles. Two journal articles from this sector combined secondary students with their educators while another journal article combined secondary and primary students for study. The higher education sector was the least researched sector with 5 journal articles. This emergent gap will be discussed further in the *Discussion* section.

Emergent Themes

Two major themes of design literacy in literature were uncovered from the SQLR. The two themes emerged from: a) sum of tabulated results, b) reviewing the broad and specific topics and, c) author's conclusion after analysing the results. These two emergent themes of design literacy relate to the findings under the *Disciplinary Field:*

1. 1) Design literacy for *making things in the physical world* is representative of secondary education sector of general education
2. 2) Design literacy for *making meanings in the digital environment* is representative of higher education. Figure 2 shows the themes and connection:

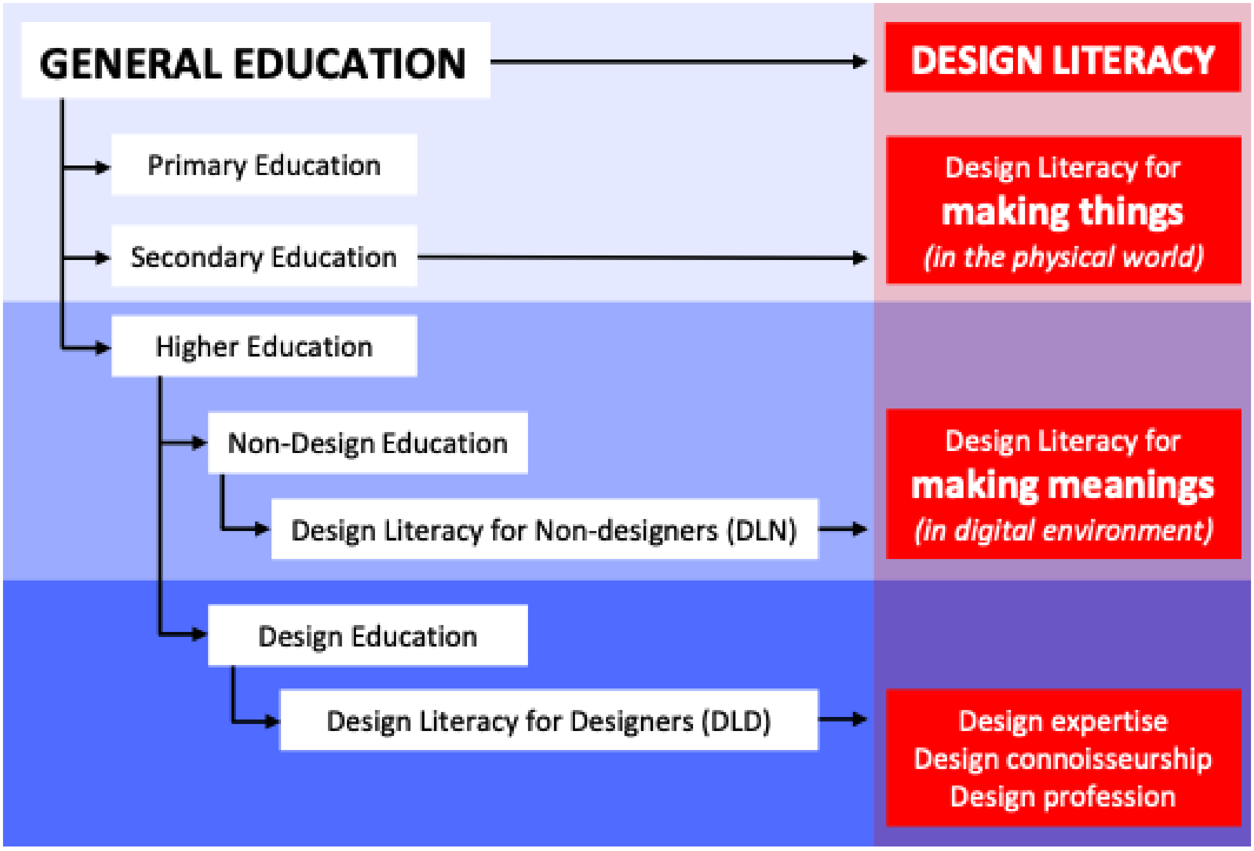

Figure 2 Design literacy primarily in Secondary Education is about making things. Design literacy in Higher Education for non-designers (DLN) is about making meanings. Design literacy for designers (DLD) is about building expertise, connoisseurship, and profession.

In addition, these emergent themes correlate with Cross'(1982) rationale of including design in general education and his conclusion that design literacy supports the development of concrete (making things) and iconic (making meanings) modes of cognition in everyone.

'Design literacy for making things in the physical world'

Nine of the 16 journal articles (56%) discussed design literacy for making things in the physical world from - designing longer-lasting products (Nielsen & Brænne, 2013), place-based design camp (Wright et al., 2018), arts and crafts for primary and secondary education (Lutnæs, 2020; Maus, 2019a, 2019b), students' stance towards inquiry to a wicked problem in a maker setting

(Christensen et al., 2016; Christensen et al., 2018), and developing design literacy among students using design critique (Yorgancıoğlu & Tunali, 2020). The journal articles cover interesting topics, however insights into the making of things in the physical world is not the focus of this SQLR.

'Design literacy for making meanings in the digital environment'

Six journal articles (38%) fall under this theme. The meagre results indicate that this theme is emerging and has a lot of potential for research. The research topics are diverse with no overlapping scope: defining the role of affect in online literacies (Ehret et al., 2018), exploring personas to foster empathy (Haag & Marsden, 2018), critique of digital design literacy as production of digital forms (Pangrazio, 2016), advocating human-centred literacy for the digital age (Pacione, 2010), and promoting interest-driven practices in a technology classroom (Baradaran Rahimi & Kim, 2018). One journal article studies the interactivity feature for interaction design that covers both the physical and digital dimension (Lim et al., 2011). The articles describe the meaning-making attributes of design literacy in higher education as visual, verbal and social articulations of non-linear information that are absent in the physical making of products. It is different from the material nature of making things and the textual nature of learning in the physical world where written or printed text is the norm.

Finally, Lerner's (2018) lone article (6%) does not cover either the *making of things* nor *meaning making* but rather discusses about how design literacy increases aesthetic growth with visual-spatial skills.

Discussion

The meagre number of journal articles (16) reviewed in this SQLR vis-a-vis the diversity of topics, field subjects, and research methods prevented direct comparison of results and generalisation of topics. Two issues raised in the *Results* section are discussed in detail: the popularity of design literacy for sustainability in secondary education, or *design literacy for making things*, and the meagre research in higher education and its implications on the theme *design literacy for making meanings*.

As a background information, an inquiry into the state of design literacy after the EDLB directive was sought. The SQLR showed that European countries had the most publication, represented by Norway (4) and Denmark (2). The remaining articles came from non-European countries led by the USA with 4 articles. These articles demonstrate the adoption of the EDLB directive #20 – "to raise design literacy awareness by fostering a culture of *design learning for all* at every level of the education system" (Thomson & Koskinen, 2012, p. 73).The SQLR revealed there were seven publications (44%) on secondary education. All the articles discuss sustainability issues with regards to the *making of things* in the physical world. The situated practice of design literacy in secondary education is "to build awareness through making" (Lutnæs, 2020, p. 13) by applying design thinking to spark innovation, civic participation and responsible citizenship in students.

On the other hand, five articles (31%) from the SQLR pertains to research in higher education. These articles demonstrate the adoption of EDLB directive #21 – "to support the development of design competencies for the 21st century by embedding the strategic role of *design across disciplines in higher education*" (Thomson & Koskinen, 2012, p. 73). This emergent gap can be attributed to the following reasons: a) the challenge and complexity of embedding design literacy in non-design curriculum, and b) the absence of an international governing body that advocates design literacy and champion its inclusion and identity in disciplines beyond design-allied courses. The EDLB is a good precursor. Sharon Poggenpohl (2008) raises the concern in design that “other disciplines discover its methods of thinking and development and perhaps presume to poach on its intellectual and creative territory”(p. 234). An example is the adaptation of design thinking in IT software development where it is called by another name - Agile Method (Dobrigkeit & de Paula, 2019; Schneider, 2017). To close this gap, design education scholars need to take the lead in conducting research that identifies and reinforces design education’s intrinsic contribution across disciplines. Design scholars have a serious stake in steering and stimulating design literacy studies across disciplines particularly in the expanding frontiers of the digital environment and the emerging knowledge economy.

The SQLR identified the emerging theme of *design literacy for making meaning* as the situated practice of design literacy in higher education. Design literacy’s affinity with the digital environment is undeniable. James E. Porter (2007) describes the digital environment as the use of *technology-as-cultural-space* or *technology-as-production-space* or the place where people live and not just a medium for communication. Anne Balsamo (2009) states that Design is the *practice of techno-cultural reproduction* (p. 2), stating that the practice of Design is akin to the skills of participatory culture (Jenkins, 2009) that supports design literacy in the digital environment. Digital technology has transformed learning environments, enabling online or distance learning (Moore et al., 2011) to emerge. Ilana Snyder (2008) observes that the digital environment is where students’ learning and literacy happen but is generally considered an extra-curricular space that is not reflected in most curriculum. The digital environment supported the online migration of higher education’s learning experiences during the pandemic. Higher education’s role in society is important. Higher education leads research and curriculum development in response to societal changes and market demands (Wright et al., 2013). It is where students learn discipline-specific skills and technical knowledge to prepare them to work in industries of their choice (Jackson, 2015). Higher education is an important platform to prepare students for employability in the knowledge economy (Choy & Delahaye, 2011; Rowe & Zegwaard, 2017). As workplaces are transformed by digital technologies, labor-intensive work associated with production of material culture is becoming obsolete. Graduates face a more complex digital workplace requiring high-level skills and tacit knowledge. They are expected to manage the wicked nature of real-world problems in knowledge-intensive industries (Kabir & Carayannis, 2013). Design literacy in higher education builds students’ collaborative mindset with the skills of participatory culture and develops inquiring, empathic mindset with design thinking to help them become creative problem-solvers and changemakers with the ability to create their desirable futures.

Limitations of the Study

All research studies including SQLRs, have shortcomings and limitations. The SQLR undertaken is considered a *benchmark review* in mapping and identifying literature from purely peer-reviewed journal articles containing the keywords ‘design literacy’ and ‘higher education’. This article is a *starting point* to initiate discourses on cross-disciplinary design literacy research in higher education. The author acknowledges that grey literature may offer rich perspective of design literacy but was not included in this SQLR because of challenges, resource limitations, or strategic considerations. First, identifying them in regular online or library search was challenging because some were listed as 'citations' only. Second, some literatures were not available in full text, required special access, or under embargo. Third, with those that were accessed, theses/dissertations and book references require time and energy that takes away these resources from reviewing other literature. The author used stringent inclusion criteria to investigate how SQLR works. The implication of this rigorous approach may have resulted in the low turnout of journal articles for review. The search phrase used was strictly *design literacy* and omitted phrases like *design capacity*, *technological literacy*, *design thinking* or other synonymous phrases for clarity and brevity of search to seriously track the use of *design literacy* as a term and field of study. Future studies may investigate how the term *design literacy* may be interwoven or conflated with traditional concepts or fused with other terms. This article serves a starting point for contemporary and future considerations of the topic. Despite the limitations, this article's benchmark review and SQLR findings may modestly contribute to advancing the study of design literacy.

Conclusion

Design literacy is a relatively new research area. A systematic quantitative literature review (SQLR) was conducted to serve as a benchmark review to explore its potential as an essential literacy for the digital age. Design literacy develops natural abilities to solve real-world, wicked problems by supporting the development of concrete (making things) and iconic (making meanings) modes of cognition in everyone. Design literacy supports nonverbal thought and communication for the development of tacit knowledge that is essential in today's knowledge economy.

The SQLR identified 16 journal articles using clear selection criteria from 12 databases. The shortlisted articles were meagre in quantity but provided rich information to describe the emergent characteristic of design literacy in general education to inform the author's interest in higher education. There was reservation to conduct SQLR at the start of review, but the merits of this method became apparent in the end. The SQLR provided clear narrative with numbers. It was helpful in establishing baseline information on design literacy and map the breadth of literature as an emerging topic. Early career researchers may benefit from the simplicity of its process using entry-level research skills. It was useful for addressing specific questions of *who, what, where* and *when* based on specific key data search where knowledge of the research topic is minimal. SQLR is favorable to early career researchers who are novices on a topic and does not yet possess the breadth of knowledge that experts in the field profess to undertake a narrative review.

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Appendix A

Table 1: Database Search Result (Complete)

Resource	Search Terms	Search Type	Date Conducted	Initial Results	Final Results	Notes	Papers used
Google Scholar	("design literacy") AND ("higher education" OR HE OR tertiary OR " university students)	Advance search	13 December 2020	1760	Last 10 years - 1210 Peer reviewed - 22 Journal article - 22		16
ProQuest				718	Last 10 years - 361 Peer reviewed - 52 Journal article - 52	2 duplicates from Google Scholar (Baradaran, Christensen)	6
Griffith Library Database				212	Last 10 years - 137 Peer reviewed - 68 Journal article - 66	1 duplicate from Griffith (Hung),	8
SpringerLink				134	Last 10 years - 109 Peer reviewed - 18 Journal article - 18	6 duplicates from ProQuest (Atkinson, Wright, Haag, Aitken, Mosley, Christensen), 1 from Griffith (Gravel)	1
JSTOR				75	Last 10 years - 27 Peer reviewed - 24 Journal article - 17	2 duplicates from Google Scholar (Parsons, Price-Dennis), 1 from Sage (Barba)	1
Web of Science	("design literacy")			36	Last 10 years - 29 Peer reviewed - 18 Journal article - 18	1 duplicate from Google Scholar (Lerner),	2
Design and Applied Arts Index (DAAI)	("design literacy") AND ("higher education" OR HE OR tertiary OR " university students)			30	Last 10 years - 15 Peer reviewed - 12 Journal article - 12	1 duplicate from ProQuest (Lim)	2
Taylor and Francis				29	Last 10 years - 12 Peer reviewed - 12 Journal article - 12		2
SAGE				6	Last 10 years - 6 Peer reviewed - 6 Journal article - 6	1 duplicate from Griffith (Ewenstein), 1 from Scopus (Barba)	1
Scopus		Basic search		3	Last 10 years - 3 Peer reviewed - 1 Journal article - 1	1 duplicate from Google Scholar (Melles)	1
ERIC				1	Last 10 years - 1 Peer reviewed - 1 Journal article - 1	1 duplicate from ProQuest (Marciano)	1
Bloomsbury Design Library				0	Last 10 years - 0 Peer reviewed - 0 Journal article - 0		0
Total					Journal articles - **225**		**41**