Book Review

Enkindling "gestaltic" stimulation of knowledge encounters through perspectives in practice: Affordances of design-based concept learning

A review of Ineke Henze & Marc J de Vries (Eds.) (2021). *Design-Based Concept Learning in Science and Technology Education*, Brill/Sense Publishers, The Netherlands.

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Aim, purpose and organisational framework

The book is a part of the series of publications on International Technology Education Studies. It addresses an emerging niche area in learning, situated at the convergent interface of design and learning of concepts in science and technology. Emerging from any cross-disciplinary overlap or convergence is the challenge of identity, which pertains to examining the kind, purpose and outcome of overlap in domains. This includes examining the nature and extent of overlap, the conditions and considerations, and the productive emergence achieved in the process. In the same breath, this book captures experiences, insights and reflections of practitioners engaged with design-based learning concept learning (DBCL) from diverse domains of practice. Structurally, the book is organised into five parts. A total of 16 chapters unfolds in: Part 1 (2 chapters) as an introduction which foregrounds the theoretical positioning; Parts 2 (5 chapters) & 3 (5 chapters) dedicated to concepts in domains of Science and Engineering/Technology, respectively; Part 3 (3 chapters) is about methods and approaches, and Part 4 on the conclusion (1 chapter) consists of a reflective piece and possibilities ahead.

The succinct preface by editors acknowledges the efforts towards convergence or a meeting of three rivulets salient to learning: concepts, design-based processes, and multi-disciplinarity in education. Incidentally, these rivulets respectively symbolise and represent the content, process and (systems) approach features that shape learning. Much of the contributions are from the researchers in Delft University suggesting an effort towards synthesis with DBCL as a larger framework for paradigmatic reconciliation of practices from the various learning domains. There are a few contributions from Israel, Sweden and the USA, which offer perspectives from different contexts. While the contributions serve to instantiate DBCL experiences, they also bring flavours of interpretations and diverse forms of accommodating design in practice.

Conceptual head-start

A reader provoked by the book title would be keen on understanding what DBCL implies, how it is characterised, and learn what unique facets of learning may come to the fore following such an approach. Counter to this intuitive flow is the first part on Introduction, which consists of two chapters, one on the formulation of DBCL and the other engaging with the notion of integrated Science, Technology, Engineering and Mathematics (iSTEM) Education. At the onset, the first chapter by the editors, Henze and de Vries, posits that design-based learning belongs to the 'family' of social constructivist approaches to learning. While a familial association with inquiry-based, project-based, problem-based and design-based learning is made, there is a need to strengthen the identity or distinctiveness of DBCL as an approach. The chapter briefly navigates through the notion of concepts as being abstract in nature and the learning of concepts as cognitive re-conceptualisation. The discussion follows on with a thread on concept learning through design which foregrounds the valued contribution of design experience in making abstract concepts more tangible or operable and the use of design iterations for systematically enhancing knowledge. The next thread in this chapter focuses on agentic role of teacher in design-based learning. The chapter culminates by giving an overview of the organisation of parts and a brief on the upcoming chapters (Chapters 2 to 15).

The second chapter by de Vries affirms the role of design activities for integrating elements from S, T, E, M disciplines. DBCL is a case exemplification of iSTEM. The chapter draws parallels between the nature of science and nature of design, making a case for design enabled integration of STEM domains. The possibilities include meaningful engagement with otherwise abstracted concepts; enrichment of knowledge elements across domains; scope for addressing pre-formed, intuitive, alternate and (mis)conceptions; and developing insights into design process. One of the critical arguments developed is that dealing with an increasing number of abstract concepts coincides with a progressive employment of "epistemic" filters as learners advance in concept levels and across learning grades within a knowledge domain. This explains the gap between the reality and abstracted knowledge that a learner faces during learning, leading to a "cognitive conflict". It is argued that the DBCL experiences can form the motivational entries for enriching formal, domain concepts.

A quick reflection at this juncture elicits some thoughts. Literature in design (Cross 2006) acknowledges that design is a discipline, which is characterised by unique principles and forms of knowledge, designerly process of engagement and specific outcomes. Thus, mediations involving design proffer potentials for gaining insights about social realities and experiences, learn and know more about designing itself as well as meet an instrumental role, which involves pressing into service, the notion of design or designerly processes towards envisioning solution for an ill-structured problem. The collection of articles seems to subscribe to the latter, whereby the intent is to harness design thinking for the instrumental goal of domain-specific, conceptual learning. An interchangeable use of design-based learning (DBL) and DBCL in the book leaves a subtle, lingering dilemma about the salience of a distinctive characterisation. It is surprising that although the discussion initiated with social constructivism in the first chapter, the thread of ideas and closing emphasis in the second chapter on integrative learning has been on cognitive conflict (dissonance), which hinges upon personal constructivism. The dynamics of conflicts arising and being handled in social scenarios embedded within political and cultural landscapes of learning, need attention. Let's now turn to the next two parts of the book.

Domains, Concepts and Designerly perspectives

Teaching learning is a planned, intentional and dynamic activity. While instruction and pedagogies can be systematically developed and translated into practice, the processes of orchestrating teaching learning through 'designerly ways' (Cross, 2006) with attention to the conceptual content along with socio-cognitive, emotive and reflective discourses is critical for making learning contextually authentic and meaningful. Efforts to consciously re-align content can contextualise learning, build iterative reflection, render possibilities for meaningful application and facilitate transfer of knowledge and skills. The parts two and three of the book engage with experiences of orchestrating the conceptual content in STEM domains. The chapters three to twelve represent a diverse set of domain-specific experiences, guided by an effort to integrate design-based aspects for enriching process as well as outcomes of learning. Evidently, a differential absorption of the notion of design manifests in the varied focus and emphasis in the experiences reported.

Chapter three by Bulte, Meijer and Pilot claims for a conceptually enriching prospect in a different representation of chemistry content contoured on design-based student tasks as opposed to the hierarchised contingency of conceptual ideas in conventional curricula. The DBCL perspective in chemistry foregrounds contextualising content in a manner that draws attention of learners to inquiring meso-structures thereby bringing into focus the conceptual relationship between macro and micro-thinking. The authors locate the DBCL effort in the theoretical framework on activity theory and exemplify an emergent instructional design for acquiring the concept of nature of matter at the secondary school level through an engagement with design-based task.

The fourth chapter by Apedoe, Ellefson, and Schunn argues for the need to support concept acquisition and change through a systematic process of learning cycle that interlaces dialogue between elements of design and science. The authors emphasise the pedagogic value of projects in encouraging design thinking that affords use of knowledge of materials and focal concepts in secondary school chemistry to develop a sense of big-ideas in connected subsystems of a larger functional system such as the heating/cooling system. A case is made for how a DBCL project allows scope for addressing alternative, pre- or misconceptions held by students as well steers their understanding towards designing a realisable prototype.

Chapter five by Breukelen details the task processes and scaffolding strategies that contributed to an enhanced students' performance and conceptual grasp of ideas on circuits and electricity. The author chooses to position the study at the interface of cognitive frameworks of content acquisition involving knowing and application, processes supporting conceptual change and problem-based scenarios in learning. The DBCL experience illustrates the use of FITS (focus on challenge, investigate scientifically, technological design knowledge application and synergy of science and technology) as a pedagogic model for realising a "design-based science interference". The learning task encouraging the designing of a circuit affords an extension of ideas in electricity and facilitated meaningful discussion on conceptual nuances among the students and the teacher.

The next chapter by Dopplet and Barak reports a DBCL experience concerning electronics and mechatronics at the middle and high school levels in two cultural settings of practice, Israel and the USA. The authors emphasise the value of design processes in engagement with projects and position the DBCL experience within the pedagogical orientations of problem-, project-based and systems thinking. While design projects can support learning of concepts in physics and engineering, the authors simultaneously underscore the need for a critical interweaving of professional development and formative assessment practices along with the DBCL practice.

Chapter seven by Spandow foregrounds the salience of designerly language of modelling. The author signifies attention to historic developments in the field, using models for contextualising integrals and differentials, and demonstrates how working with models can mediate developing mathematical understanding. The author claims that modelling can enable application of mathematical ideas for seeking societal welfare. The DBCL experience positioned with the model-based learning framework emphasises the role of modelling, history-informed teaching and use of stock-and-flow software for grounding concepts in calculus at high school level.

Gómez Puente in chapter eight elaborates on a DBCL experience involving students and teachers from the Bachelor in Engineering programme. The work positioned in project-based learning framework discusses the valued impact of design process approach in meaningfully supporting students and teachers to accomplish engineering projects. Using project case examples, the author asserts the salience of DBCL as an operative framework of instruction. The chapter demonstrates how performance of students increased significantly for the teams working through a DBCL approach of project engagement.

Chapter nine by Svensson discusses the engagement involving students and their teachers in Swedish secondary schools. Using inquiry and modelling as principles of DBCL, the author makes a case for directing learners' attention to thinking about systems in everyday lives, and recognise the interplay of the critical pillars of technology, namely; information, matter and energy in appreciating the components, connectedness and flow in everyday functional systems such as the transport system. Locating the DBCL experience within a project-based learning paradigm, the author argues for a conceptual and instructional framework to enhance learning.

The tenth chapter by de Haan-Topolscak and Smits represents an investigation into the process designing itself. The authors report a study undertaken with secondary school students opting Technasium. The study explored how students engaged with the idea of requirements in design briefs. While design briefs ought to realistically reveal about the structure and functional aspects of designed artefact, the students seemed to focus on what they would desire to see (an ambitious envisaging) of the artefact. They also did not exhibit pre-knowledge about the significance and purported function of design briefs. The authors suggest a need for foregrounding and discussing this knowledge in DBCL learning engagements.

Chapter eleven by Wells relates to DBCL experience with engineering students, pursuing a course in biotechnology in the USA. The author develops a case for how a 'design-based biotechnical learning framework' can engage learners in carefully sequenced problem scenarios which contribute to promoting the STEM conceptual understanding. The author demonstrates how a designed learning engagement with convergent and divergent questioning which are at the core of PIRPOSAL (problem identification, ideation, research, potential solutions, optimization, solution evaluation, alterations, and learned outcomes) process, can be an effective pedagogical model for fostering learning and helps address larger technological concerns, such as the use of renewal energy for supporting sustainable living.

The study reported by Stevens, Kopnina, Mulder and de Vries in Chapter twelve involved industrial design engineering students in the Netherlands to integrate from an exposure to biomimicry thinking, the analogical relationship between features of structure-function salience in biological world onto artifactual design. The pedagogical model of 'design lens to biology' allowed for combining elements of project-based learning, analogical reasoning, attending to life principles and employing biomimicry thinking. The authors demonstrate that the DBCL experience encouraged students to strive for an explicit transfer of form, process or systems idea to conceptualise and design engineer an artifactual outcome.

Common to chapters three to twelve is a conscious effort to contour and enrich conceptual learning through designerly thinking. Of the ten chapters, spread over two parts, seven reported experiences engaging students from secondary or high school levels. Three contributions (by Breukelen, Gómez Puente and Svensson) explicitly attended to teachers as participants in their respective studies. Interestingly, all the experiences seemed to be guided by an effort to gain insights into either developing an *instructional framework* or *pedagogical model*, so as to nurture attention to conceptual content. The contributors seemed to accommodate design as enriching the quality of learning variously, either by choosing to *focus on design elements* (for example, attention to meso-structures for mediating relationship between macro- and micro-thinking by Breukelen; modelling and history-informed teaching by Spandow; or a focus on information, matter and energy in enabling systems thinking by Svensson) or by demonstrating an *adaptive emphasis on design process* (for example, 7-step learning cycle by Apedoe et al., design process by Dopplet & Barak; or PIRPOSAL by Wells).

The bipartite presentation of chapters as Science and Technology/Engineering concepts may raise several questions for stretching our minds: (i) How does the organisation of part two build on part one of the book, isn't the organisation antithetical to multidisciplinary foregrounding in the first part? (ii) Are the concepts covered through the domain constituency unique or distinctive (in their historic evolution, nature or affordances) and therefore call for a separation? (iii) How is the engagement with domain concepts and its treatment contoured by differential absorption of design-based learning orientations in domains of practice? (iv) Does the selection of experiences support an argument of design-based engagements having an unequivocal impact on concept learning, irrespective of the differences in perceptual (historic, social or disciplinary) proclivities toward imbibing the principles and attributes of designerly engagement? (v) Is the demarcation a means to showcase the distinct disciplinary sources of efforts towards absorbing a DBL practice? Such a flurry of questions arising from a glance at the organisational structure may be parked for some time in order to immerse with the unfolding ideas as they come along. Overall, they capture an "epistemic ferment" driven by efforts to make teaching learning effective and meaningful on one hand, and align the learning processes with designerly ways on the other hand.

Building further from the "epistemic ferment"

One of the larger questions that may come to the reader is about the substantive generalisation that can be drawn from the experiential musings of what gets qualified as DBCL. The fourth part of the book on Methods and Approaches seems to be addressing this concern.

Chapter thirteen by van der Sanden and Wehrmann argues for an epistemic positioning of design thinking as a 'mind-set' or mental model of the designer, that needs to be systematically implanted, developed and nurtured through an engagement with a community of practice. The arguments draw upon insights from Communication Design for Innovation (CDI) program at Delft University. The authors demonstrate learning in loop through a discussion of some works of students engaged in designing. While design-based learning has been argued as fostering collaborative innovation through the triple-loop model of learning, design thinking is also acknowledged for being vulnerable as it involves coping with uncertainties, awareness of one's own biases and yet keeping the mind open to ideas.

Another interesting strand drawn from experiences relates to the role of teacher in noticing and supporting the work of learners. Chapter fourteen by Stammes, Henze, Barendsen and de Vries employed the dynamic construct of teacher noticing, accessed through plans and drawings. The study not just vouches for rigorous conceptual gains in chemical thinking through an attention to nuances of student-teacher interactions but also makes an empirically-guided, evidentially-informed case for using noticing as a means to probing thinking and enhancing teachers' calibrated role in supporting designerly thinking.

Chapter fifteen by Sheoratan, Henze, Barendsen and de Vries is a continuation of the thread on teachers' role, where the verbal scaffolding offered by in-service teachers in guiding design assignments of learners has been studied. The analysis brought to the surface the different types of questions and feedback strategies used by teachers to exercise different degrees of control and help scaffold students' work. Interestingly, the directed scaffolding in terms of concept learning was found to much lesser as compared to engagement with learning processes, suggesting the critical role of teacher in calibrated leveraging of students' agency. On reflection, one realises that the book began and ended by drawing upon experiences from integrating design in teaching learning of chemistry.

Consolidation and intended takeaways

Chapter sixteen by the editors is the concluding chapter and also the last part of book. It offers a helpful analytical consolidation and invokes some critical leads for thinking. Three themes emanating from the collective DBCL experiences are discussed: variety in DBCL practice, attending to diverse roles by teacher, and nature of learning supported through DBCL. A fascinating attribute of this chapter is a combination of generalisation and inferential abstractions. For instance, the editors surmise on the flexible nature of DBCL in adapting to levels of conceptual complexities, topics and epistemological and pedagogical approaches. At the same time, several inferential claims are drawn from the thematic discussions. This includes, the correlation of abstract concepts and the plausibility of DBCL as relatively more amenable for the higher educational levels, direct instruction as a pre-requisite to inquiry and design for necessitating concept learning, the need for teachers having pedagogical content knowledge along with willingness to experiment and reflect, and functional invariance of design-based activities in meeting the three dimensions of science learning, mentioned in NGSS

(2013), namely; disciplinary core ideas, cross-cutting concepts, and addressing science and engineering practices. The chapter culminates with a call to researchers and innovators to identify, engage and address challenges in realising design as a context for conceptual learning.

Critical gatherings and closing thoughts

The book title embraces design and concept learning in the same breadth. The reader is enticed into expecting an interweaving that may offer a refreshingly different perspective, other than the one offered either uniquely through a concept-oriented or a design-oriented imagination. The attempt to rationalise and ground the idea of DBCL from pedagogical and epistemological standpoints in first two chapters does not catch momentum. The contributions from disciplinary domains seem to reflect a struggle of scheme alignment. While the chapters unfold some remarkable works in their own right, the effort to operationalise deep-seated connections with the idea and process of design needs further development. The conscious effort to reclaim identity of design paradigm in many cases comes from a compromise. The compromise is achieved, either by attending to a design characteristic (for example, addressing ill-structured problems, investigative problem scoping, iterative process, use of designerly language consisting of non-verbal codes, drawings, cognitive modelling, etc.) or relating to designerly process (for example, conjecturing, collaborative negotiations, redesigning, appropriating, etc.). While design seems to offer a paradigmatic scheme, the reader jostles through diverse pedagogical frameworks which include, project-, problem-, design-based science, learning by design, and some other models discussed in various contributions. One wonders if a clash of the two cultures of sciences and design, articulated by Cross (2006), be a reason for the felt conceptual effervescence? Positioning DBCL as a mere variant in the family constellation of allied pedagogies affirms to a conformational reconciliation with elements of design paradigm rather than carving a distinctive epistemological and conceptual niche.

The strength of this book lies in being accommodative of the multiple ways in which the elements of design thinking have been internalised in domains of practice. Identifying with DBCL as means to realising internationalities through meaningful, educative experiences is a powerful and pragmatic road ahead. The collection of articles seemed to stimulate the need for relational examining of knowledge and practice, in a “gestaltic” vein. Hergenhahn and Olson (2001) elaborate that *gestalten* (plural of *gestalt*) represents meaningful configurations or patterns that ought to be examined at a molar (rather than molecular) level or as a phenomenon in its entirety. The several contributions may serve as exemplars for not just schematising the confluence of design and discipline-oriented concepts, but also to encourage initiatives that pursue the use of designerly thinking for epistemologically and conceptually shaping the terrain of educational practice in intellectually stimulating ways. The book would be useful for any reader seeking a reinvigoration in thinking and experimenting with curricular and pedagogic practice. The book will appeal to curricular practitioners and researchers in STEM education as well as in disciplinary domains, educationists, teacher educators and teachers at different levels of educational practice.

References

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