Perspectives on curriculum design: comparing the spiral and the network models

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Introduction

Does one approach fit all when it comes to curriculum design? In debates on curriculum design, educators have argued that a curriculum model should take into account the differing knowledge structures of different subjects. Subjects such as Mathematics and Science are generally defined as well-structured knowledge domains, characterised by a linearity in learning objectives, and well-defined and predictable learning outcomes. Less structured subjects such as the arts and humanities could, however, benefit from models that encompass a different approach to learning. Two competing perspectives on curriculum design have emerged: the spiral model developed by Bruner (1960) and non-linear models based on processes of learning in different knowledge domains (Efland, 1995, 2000; Yang, 2000). Research on curriculum design has tended to focus on the needs of Science, Technology, Engineering and Mathematics (STEM) subjects. Many alternative models to the spiral have come from arts-based disciplines, in particular visual arts.[1]

This article contributes to the ongoing debate about curriculum design in different subjects. It details the key characteristics of Bruner's spiral model, and presents the main arguments made in favour of adopting flexible and non-linear curriculum models in specific subjects. We discuss a number of alternatives to the spiral model and analyse the relative strengths and weaknesses of these different approaches. The conclusion offers a discussion of implications of our findings for further research in curriculum design.

Background: the spiral curriculum

Bruner (1960) developed the spiral curriculum model by drawing on the way that concepts and knowledge are structured in the physical sciences. This was considered to be equally applicable to the arts and humanities. Learning is visualised as a spiral upwards from basic to advanced concepts, with topics being revisited at increasing levels of complexity as the spiral loops round. The process of reinforcement in learning is a key feature of the spiral curriculum. Each return visit has additional objectives and presents fresh learning opportunities. In a spiral curriculum, attention is paid to both the scope and sequence of topics. Bruner felt it was important that learners obtain the most "fundamental understanding" of a subject by having a solid grasp of the underlying principles of that subject (Bruner, 1960, p.31). In particular, he speculated that if learners were introduced to specific topics or skills without a connection to core principles in the broader field of knowledge, they would:

a) be unable to generalise from what has been learned and apply this in other scenarios;

b) find little 'reward' in terms of intellectual excitement; and

c) be more likely to forget what they have learned, if this knowledge is not structurally organised in terms of principles and ideas (Bruner, 1960, pp.31–32).

Knowledge structures

At the heart of the spiral curriculum theory is Bruner's assertion that "any subject can be taught effectively in some intellectually honest form to any child at any stage of development" (Bruner, 1960, p.33). This signals his firm belief that the spiral curriculum could apply to all subjects. Yet, this assumption has also formed the key contention that advocates of alternative models have brought against Bruner's model.

The assumption that it is possible and/or desirable to extrapolate from Science to other subjects has led to criticism of the spiral model, particularly from those concerned with the arts (Efland, 1995). Drawing on findings in cognitive research, these critiques have highlighted that specific knowledge domains are structured differently from the STEM topics on which Bruner based his spiral model. They have argued that the relative ill-structuredness of some domains is a poor fit with processes of learning captured by the spiral. In this sense, the spiral curriculum is found to have disadvantages in its application to less-structured knowledge domains.

Feltovich et al. (1993) used the term 'ill-structured' to describe domains which require a learner to synthesise many different concepts, and patterns of concepts, on a case-by-case basis. This type of knowledge is found in many fields including law, literary criticism, history and philosophy: any subject where there is an "absence of rules or generalizations that apply to numerous cases" (Efland, 2002, p.84). Finding "a key idea around which to organize instruction" is also less evident in subjects that rely less on the study of over-arching principles, and more on the in-depth study of specific cases (Efland, 2000, p.278; 2002). Learning through understanding laws, axioms or theorems, where problems have a single correct solution, is more common in well-structured subjects (Short, 1995; 1998). This consistency is less common in some of the social sciences, humanities and arts (Alexander et al., 1991; Short, 1998). A subject's underlying structure, it is argued, has key implications for learning within that subject.

Likewise, the theory of vertical and horizontal discourse (Bernstein, 1999) described different forms of knowledge as hierarchical (e.g., science) or horizontal (e.g., humanities). Hierarchical knowledge structures appear to be "motivated towards greater and greater integrating propositions, operating at more and more abstract levels" (Bernstein, 1999, p.162). Horizontal knowledge structures "consist of a series of specialised languages with specialised modes of interrogation and criteria for the construction and circulation of texts" (p.161).

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[1] In comparison, curriculum models for subjects such as Literature, languages and the humanities have not received the same level of scrutiny.

Trying to apply a single curriculum model to these two types of knowledge structures presents obvious problems. The spiral model seems to fit more naturally with the hierarchical knowledge structure of the sciences and the move towards abstract ideas.

Cognitive researchers have argued that the process of tailoring the complexity of ideas to early stages of learning constitute 'simplification strategies' (Efland, 2000) or a 'reductive bias' in the spiral model (Feltovich et al., 1993; Spiro et al., 1988). They argued that the reduction of complexity that occurs in the spiral curriculum has implications, the most notable being a single representation of ideas at the expense of multiple representations. Instead, they argued that learners should be encouraged to study ideas and concepts in all of their complexity.

Reduced complexity favours single representations (e.g., a single schema, organisational logic, line of argument, or analogy). The use of simplification in instruction is a helpful tool, particularly in early stage learning, which enables a learner to interpret a new concept using existing knowledge. However, as Spiro et al. (1988) argued, singular representations carry a risk of missing the many aspects of a complex concept, while learners may also fail to develop diversified ways of thinking. Using the example of learning in medicine, studies have argued that singular representations can form simplification strategies in learning that are obstacles for developing in-depth, advanced learning strategies at later stages (Feltovich et al., 1993; Spiro et al., 1988). Feltovich et al. (1993) described biomedicine as an ill-structured domain where "the linkage between surface features of cases and applicable concepts is irregular and rich, relational indexing and categorisations are not only particularly important but also particularly difficult for the learner to construct" (p.202). Therefore, one problem with the notion that the spiral curriculum begins with simple concepts and progresses to mastery is that it fails to recognise that for ill-structured domains the spiral model can lead to misconceptions in early learning, which persist into advanced study. However, while reductiveness is intended to make knowledge acquisition easier, Efland (2000) argued that it may lead to students not understanding what is being taught, and struggling to relate the knowledge to their own lives.

How has the spiral model been applied?

Science

Comparing science education in China to the United States, Su et al. (1995) found that Chinese students who were taught science via a spiral curriculum developed good theoretical knowledge and basic skills, while the United States took a 'layered' interdisciplinary curriculum approach where students developed good factual recall. A comparison of the science curricula of each country (Herr, 2007) showed that China taught Biology, Chemistry and Physics at each grade level between Grade 7 and 12—a 'vertical and spiral' model. The United States covered a broader range of subjects, including Environmental Science and Zoology, and taught Biology only at Grade 10, Chemistry only at Grade 11 and Physics only at Grade 12. Laboratory work in the United States was interdisciplinary. However, these comparisons do not tell us much about the relative merit of each approach, given cultural and societal differences between the countries' education systems.

Medicine

Harden and Stamper (1999) related how the spiral model informed the University of Dundee medical course. Year 1 focuses on structure, function and behaviour. In Years 2 and 3, students revisit these concepts when studying abnormal structure, function and behaviour. This knowledge is then related to clinical practice in Years 4 and 5, and finally the theory is put into practice in students' pre-registration year. In the case of medicine, it seems logical that a solid theoretical base must be the starting point before students commence practice, and the outline given by Harden and Stamper fits Bruner's theory. However, as we highlighted earlier, medicine is also characterised by its ill-structuredness.

Mathematics

In the United States, the spiral curriculum is the mostly widely used structure for school mathematics (Seely, 2009; Snider, 2004). The effectiveness of the spiral curriculum in the United States has been questioned, mainly due to perceived poor performance compared to other countries in Trends in International Mathematics and Science Study (TIMSS; Snider, 2004). Schmidt et al. (2005) created charts of common content standards for Mathematics by examining the curriculum structures of six top-performing jurisdictions (as measured by TIMSS). They found that increasing mathematical complexity was introduced as students progressed through school years with some topics forming 'buttresses' across multiple school years.[2] This was characterised as a 'staggered spiral'. They then compared this data with United States content standards and found that the United States featured longer duration of topics, with the majority of topics being covered across all the US Grades 1–8. They referred to this situation as the 'mile-wide inch-deep curriculum'. Despite the differing approaches, all countries were described as using the spiral curriculum.

Music

Swanwick (1979) proposed a set of hierarchical music learning objectives, which was later expanded to produce a model of musical development (Swanwick & Tillman, 1986). Taking Piaget's child development theories as a starting point, Swanwick and Tillman (1986) applied the concepts of *mastery* (control of sound materials), *imitation* (expressive character/accommodation) and *imaginative play* (structural relationships/assimilation) to a music learning context. They observed children aged between 3 and 9 years old in Music lessons and found that the compositions of children followed this sequence. Furthermore, with reference to other studies, they felt able to tie the stages of development to particular age groups.

Table 1: Stages of musical development

Piagetian concept	*Description of musical enactment*	*Stage*
Mastery	From sensory exploration to manipulative skills.	Ages 0–4
Imitation	Personal and idiosyncratic expression to socially shared vernacular conventions/reproducibility.	Ages 4–9
Imaginative	Speculative composition and attention to formal musical devices.	Ages 10–15
Meta-cognition	Self-awareness of thought processes and feelings in response to music.	Age 15+

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[2] One limitation of the analysis was that the aggregated data was not representative of any single one of the countries' complete curriculum.

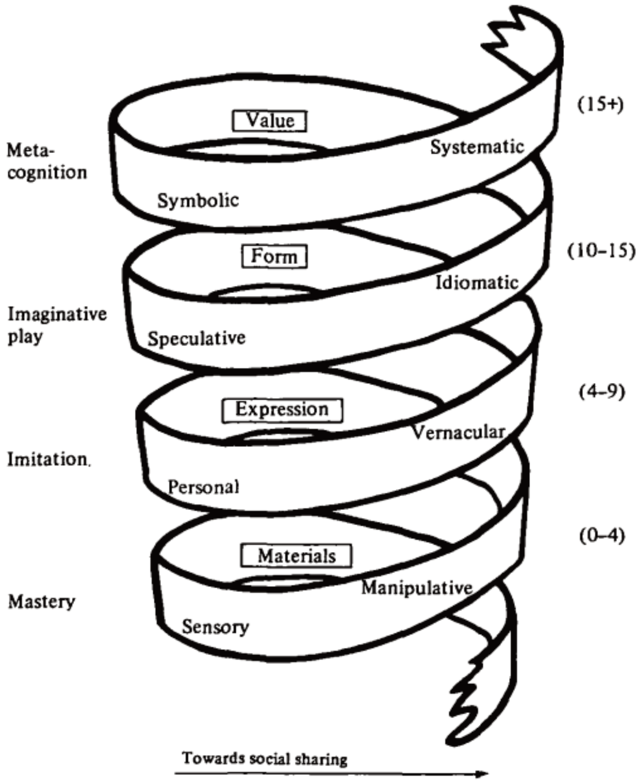

Figure 1: Spiral model of musical development (Swanwick & Tillman, 1986, p.331). © Cambridge University Press 1986, reproduced with permission.

This development model was visualised as a spiral (Figure 1).

The spiral curriculum's central concept of revisiting stages or topics is incorporated into Swanwick and Tillman's model. For example, they state that "the shift from sensory exploration towards manipulative skills […] is an on-going concern at any stage of development" (1986, p.320). Furthermore, they proposed that development stages or topics were revisited even by experienced musicians, giving the example of the exploratory behaviour entailed in familiarisation with a new instrument (1986, pp.336–337).

Swanwick later reflected on the spiral model and conceded that the Swanwick and Tillman spiral (Figure 1) was just one of a number of ways of conceptualising musical development. He argued that as well as linear and quantitative, progression in Music could also be seen as layered and qualitative, with issues such as critical judgement and audience response forming part of the model (Swanwick, 2016).

The Manhattanville Music Curriculum Project (MMCP) was an education programme that ran in the 1960s and 1970s in the United States (Moon & Humphreys, 2010). The programme aimed to reform music education and was based on the spiral curriculum model. Elements of music (dynamics, timbre, form, rhythm and pitch) were organised into cycles which repeated with increasing complexity. In the programme, students were presented with problems and they then composed and performed their responses, followed by an evaluation stage. This is an interesting contrast to the Swanwick and Tillman spiral, because the MMCP model refers directly to the subject content rather than the development stages.

Art

As evidence for his hierarchical theory of musical development, Swanwick cited the work of Hargreaves and Galton (1992). This is a hierarchical model of artistic development which describes progress in cognitive aesthetic development, drawing, writing, singing, musical representation, melodic perception and musical composition. Five phases of development are proposed: Presymbolic (ages 0–2), Figural (2–5), Schematic (5–8), Rule Systems (8–15) and Metacognitive (15+). Stages of development then populate the model; for example, the Presymbolic phase of drawing would be demonstrated by scribbling and the Rule System phase of melodic perception by analytic recognition of intervals. While not a spiral model in itself, the sequential progression of development is in keeping with the spiral philosophy.

Discussing the ARTS PROPEL[3] approach, Gardner (1989) believed that, if suitably structured, a spiral model could be valuable in arts curricula in schools. While he discounted the idea of atomistic curricular goals for the arts, he argued that sequential, holistic goals could be included in an arts curriculum and that core concepts such as style, composition and genre were revisited at increasing levels of sophistication. Gardner described these aims as a spiral model.

Advantages and disadvantages of the spiral model

Harden and Stamper (1999) noted a number of advantages to the spiral model:

- Reinforcement—it encourages retention of knowledge;
- Simple to complex—topics are introduced in a controlled way, to enable better understanding;
- Integration with other parts of the curriculum—subject silos are broken down;
- Logical sequence—attention is paid to the sequence of topics at the curriculum design stage;
- Higher level objectives—increasing complexity encourages students to move beyond recall to application of knowledge.

However, educators from different fields have suggested a number of shortcomings in the application of the spiral model. Comparing different approaches to Mathematics curricula, Snider argued that although the intent of the spiral model is to treat each concept with increasing depth at successive grade levels, the "functional result is that students acquire a superficial understanding of math concepts" (2004, p.31). She identified several aspects of the spiral design that may contribute to this:

- Superficial treatment of topics—students may fail to master important concepts as the spiral model promises further opportunities for mastery with subsequent visits;
- Those who do master the concepts are subjected to unnecessary repetition of the content which can be demotivating (Jensen, 1990);
- Topics introduced at an inappropriate rate—concepts are allotted the same amount of time whether easy or difficult to master;
- Minimisation of academic learning time[4]—the rate at which new content is introduced can mean students unsuccessfully grapple with difficult concepts, or lose interest due to a lack of challenge;

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3. ARTS PROPEL was a collaborative project implemented in the USA in the 1980s. It sought to describe the competences arts students should display: production, perception and reflection, with learning named as a core concern.

4. Academic learning time is defined as the amount of time students are 'actively, successfully, and productively engaged in learning' (Brodhagen & Gettinger, 2012).

- Insufficient cumulative review—learning reinforcement is hindered if there is too much time between visits to topics.

One notable feature of Bruner's book, *The Process of Education* (1960), is the lack of evidence offered for the efficacy of the spiral approach. The scarcity of literature assessing the impact of spiral curricula suggests that in general the spiral has been implicitly accepted as a key model for curriculum design, with limited critical reflection on its suitability across subjects. The reason for this might be, as Johnston (2012) noted, "because the spiral curriculum is often interwoven with other inquiry-based and constructivist learning approaches, it is often quite difficult to assess the effects of the *curriculum*, rather than the *delivery* of that curriculum" (pp.1–2). Alternatively, the perception of science subjects as well-structured and hierarchical may have led to an assumption that the spiral curriculum is appropriate. Educators in arts-based disciplines have argued that positivism as an influence in the development of, for example, social inquiry within the social sciences, has favoured structured approaches, such as that of the spiral model (Efland, 2002; Sullivan, 1989). The influence of positivism in research may therefore also be a reason for the lack of scrutiny in applying the spiral approach to art disciplines.

Other studies consider the structured sequencing of learning objectives within the spiral model to be a disadvantage, rather than a strength. Venable (1998) used the example of teaching art criticism to argue that inflexible sequencing may prevent learners from engaging with a topic in depth, as it creates a situation where certain outcomes are intended to be pre-cast, discouraging connections to other areas. Short (1995) similarly argued that in-depth thinking requires not only conceptual and factual knowledge, but also "cognitive flexibility [in order] to see numerous relationships between the two" (p.167). Both studies perceived these types of horizontal connections to other topics to be limited by the structured sequencing within the spiral.

Non-linear curriculum models: network and web models

Most non-linear models that have been proposed as an alternative to the spiral take the form of a 'network' or a 'web'. Webs and networks put less emphasis on linear progression in a knowledge domain and the development of discrete skills, and more emphasis on 'meaning-centred' approaches (Slattery, 2006, p.116; Efland, 2002). In these models, the learners' grasp of the interconnectedness of ideas and the importance of transfer of learning between contexts is emphasised. For instance, Perkins (1989) considered that "understanding something entails appreciating how it is 'placed' in a web of relationships that give it meaning" (p.114). In these models, the sequencing of learning objectives can be flexible, and learners can participate in the choice of their learning pathway. While web or network models have tended to emerge from art domains, they are by no means the only fields to utilise such models. For example, Cambridge Mathematics (2018) has developed an evidence-based, non-linear framework of mathematics knowledge.

Several studies have highlighted the challenges of curriculum design in ill-structured domains, and have subsequently proposed alternatives. The landscape model was proposed by Spiro et al. (1988) in response to the authors' concerns with the single knowledge representation and the reduction of complexity in the spiral model. They argued that a curriculum landscape must be criss-crossed in many directions to master its complexity, reflecting the emphasis on multiple interpretations. The 'lattice' structure was in turn proposed by Efland (1995, 2000) who drew inspiration from the landscape model. The lattice is an alternative to the spiral model, yet both are described by Efland as geometric forms constituting a representation of three factors:

a) The way knowledge is organised in an individual's knowledge base;

b) The way domains of knowledge are organised; and

c) The way content is arranged for purposes of instruction.

The lattice model specifically allows for the overlapping and interconnecting of ideas. This maintains the inherent complexity of a knowledge domain, and addresses the need for the multiple representations that Efland and his contemporaries have advocated. The complex organisation of the model enables "multiple routes of intellectual travel" between and among overlapping domains of knowledge (Efland 2000). The role of transfer—when the learner grasps common elements between two different ideas or concepts—is therefore facilitated in this model.

Efland acknowledged particular flaws in the lattice model. Specifically, he perceived a risk that the lattice could introduce too much complexity in the early stages of learning, and that it is not constrained by natural boundaries, with the potential to spread outwards. An important distinction between the lattice and the landscape model is that Spiro et al. envisaged a model of a domain awaiting discovery by exploration; in comparison, the lattice was intended to function as a "structure actively undergoing construction as learning progressed" (Efland, 2002, p.100). Addressing concerns about the risk of over complexity in the lattice model, Yang (2000) and Efland (2002) went on to propose models with more clearly defined boundaries.

The city model was proposed in order to reflect a better balance between capturing interconnectedness between ideas, and the need to avoid overwhelming the learner with detail at early stages (Efland, 2002). The model was built on the idea of learning as travel within different parts of a city, involving movement from one domain to another, and is similar to the lattice model in this regard. Efland likened curriculum plans to city plans, and stressed the feature of overlapping sets, where the same facts appear in separate domains of knowledge. Overlapping sets act as 'points of transfer', where learners familiar with knowledge in one domain have a possible entry point to begin their exploration of another domain. In this way, learners might study a painting, and learn about the historical context of the painting or the historical event that the painting depicts. The city model also gives learners agency in the learning process as they can choose the destination of travel. In travelling to unfamiliar domains, the learner can benefit from guidance provided by teachers or other knowledgeable peers who act as mediators (Efland, 2000). Efland noted that learners also have a choice in their 'method' of travel where this choice reflects their cognitive strategies; for instance, taking the underground covers a greater range of territory and is a faster mode of transport, but travelling on foot allows exploration of a topic in greater detail.

A related model is a delineated travel network (Yang, 2000), where this travel network has natural boundaries that the lattice does not. For instance, airlines do not organise flights between all cities as this would be too complex to maintain, but rather certain cities are instituted as hubs or transfer points. In curriculum terms, a hub might consist of a broad theme through which one might reach a variety of related destinations (Efland, 2002, p.103). As with Efland's city model, there are 'connecting points' that learners may revisit throughout their learning, leading to the gradual comprehension of a complex domain, or concept, over time.

Conclusion

This article has outlined the approach captured by Bruner's spiral curriculum model, its main features, and its application in varied subjects. While the spiral model has been widely applied since the 1960s in different contexts, educators from some fields have argued that the spiral is better suited to well-structured subjects. We have outlined alternative curricular models and summarised the arguments in favour of them, noting where these models go beyond the spiral's limitations, but may also have their own limitations.

The literature we have reviewed indicates two distinct views on curriculum design. The spiral's structured approach to the scope and sequencing of learning objectives ensures knowledge outcomes are pre-planned, while also enabling vertical integration within the curriculum as topics are revisited. Repeat visits of topics at increasing levels of complexity, a key feature of the spiral, also places importance on the learners' grasp of core concepts, whereby ideas are built on to achieve mastery. On the other hand, proponents of web or network models argue that learning is not always linear, that simplification strategies in learning are unhelpful, and that connections between concepts are vital for integrated learning. Beyond the vertical integration of topics within a spiral curriculum, advocates of non-linear models argue that there is a need to forge horizontal connections between ideas and knowledge domains. These type of 'network' models advocate a more flexible approach to the sequencing and scope of learning objectives, where learners also have decision-making power in their learning journey.

These ideas are presented in the literature as opposing views, with Mathematics and Science requiring a strict linear and hierarchical approach and arts subjects demanding a non-linear alternative, but in fact we have presented evidence that elements of both views can apply whether a subject is well- or ill-structured. While most of the research into alternatives to the spiral model has originated in arts contexts, our findings suggest that these considerations and conclusions can be applied to well-structured subjects as well as ill-structured, as seen with Cambridge Mathematics (2018). Likewise, some commentators have seen merit in a spiral approach for arts subjects (Swanwick & Tillman, 1986; Gardner, 1989).

While this article has highlighted how non-linear models favour greater horizontal exploration of ideas within a curriculum, the risk of overload onto students' learning in a model defined by a lack of natural boundaries is also a valid concern. Efland acknowledged that the lattice model and the risk of introducing too much complexity at the early stages of learning is an example of a tendency towards over-complexity. At the same time, it appears that little has been done to explore the opportunities within the spiral model for facilitating these types of connections. We have noted that the spiral model has a greater tendency to predetermined knowledge outcomes than the approach adopted by non-linear models. Yet the need for conceptual and factual learning that is found in the spiral model, and the need to understand key ideas, is not altogether absent in alternative models. We consider that bridging these two different perspectives provides an avenue for future work on curriculum design.

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Context matters—Adaptation guidance for developing a local curriculum from an international curriculum framework

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Colleagues across the University of Cambridge worked alongside UNICEF and Microsoft to develop the Learning Passport (LP).[1] The aim of the LP is to contribute to achieving the UNICEF goal of providing a quality education provision to the over 30 million children and youth worldwide who are unable to access a quality education provision due to disruptions caused by crisis and displacement. This area of education is often referred to as Education in Emergencies (EiE). Education in Emergencies refers to education which takes place in an emergency situation, such as a crisis or disaster which disrupts consistent education provision. The EiE landscape is diverse, with a range of learners, learning environments and facilitators. Developing a universal curriculum or learning programme to be used unilaterally across all EiE contexts would not be a logical or ethical method for providing support (Cambridge Assessment, 2020). Instead, it was decided that a blueprint curriculum framework would be created which would provide a set of minimum concepts and principles, integrated into parsimonious learning sequences. These learning sequences would then serve as knowledge-based blueprints for localised curriculum development across a variety of contexts.

The LP project resulted in a curriculum framework for Mathematics, Science and Literacy (Cambridge Assessment, 2020). Alongside this framework, Adaptation Guidance was also created. The Adaptation Guidance was directed towards curriculum experts that would be responsible for developing a localised curriculum based on the LP framework. Although intended to be used in the EiE context, this curriculum development guidance is relevant to curriculum experts across all educational contexts. With global movements of people consistently increasing in recent decades, the demographic of classrooms is changing in most urban areas and in many rural schools

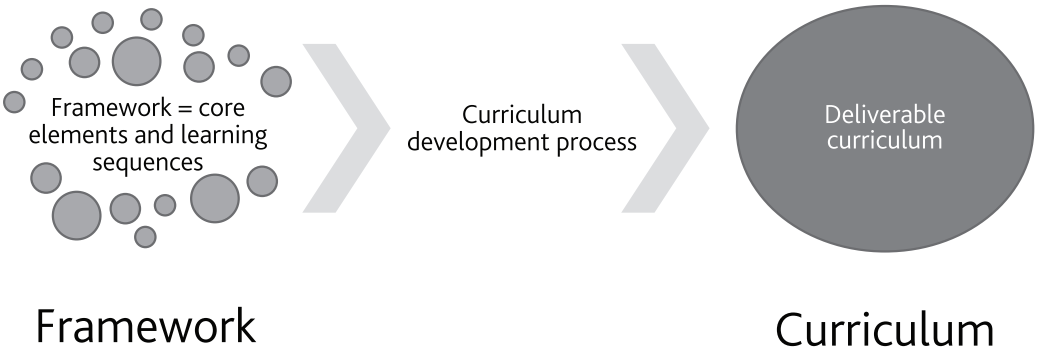

Figure 1: Developing a curriculum from a parsimonious learning framework.

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[1] More details are available at https://www.cambridge.org/files/8615/8465/3596/The_Research_and_Recommendations_Report.pdf