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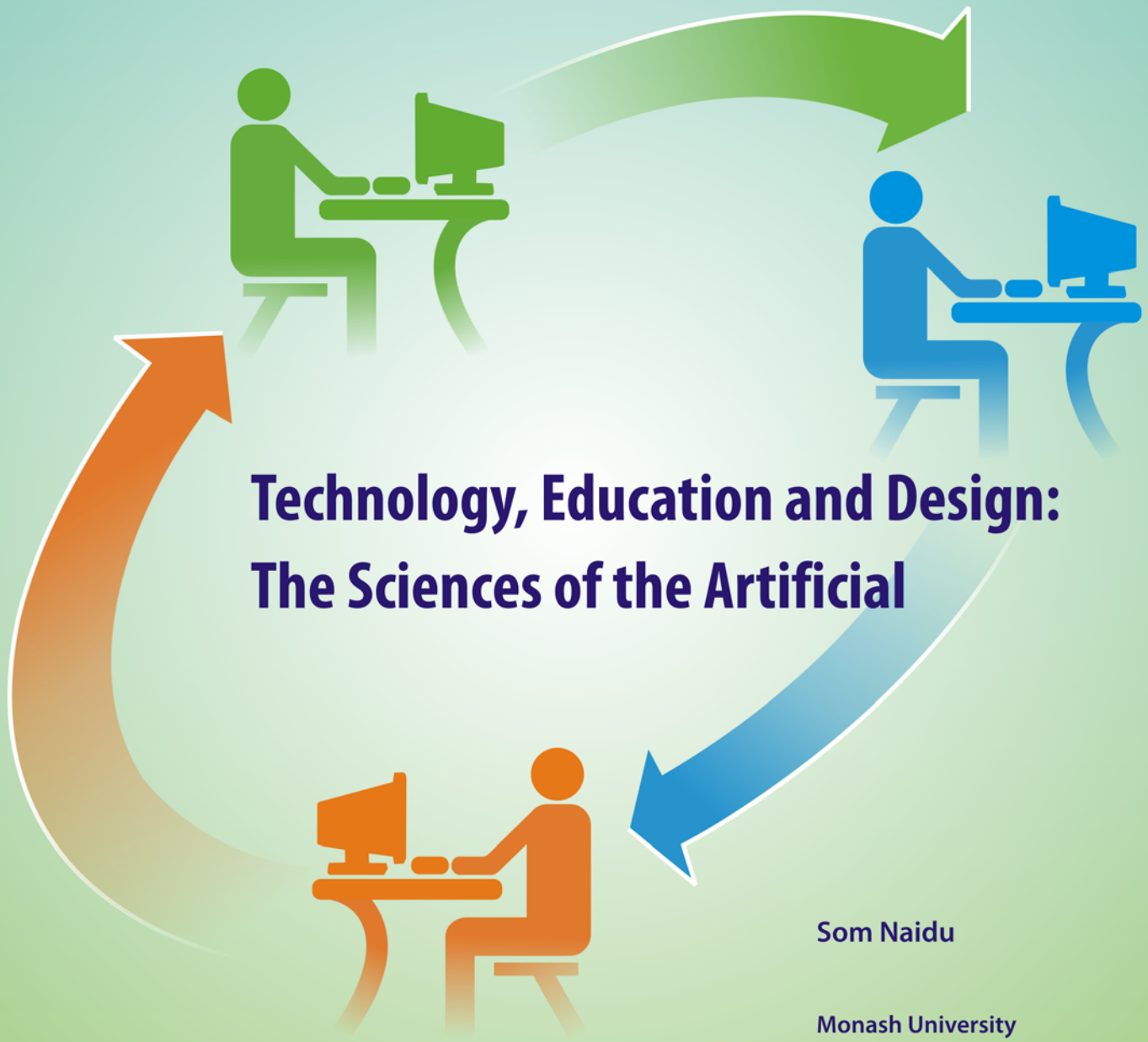

Technology, Education and Design: The Sciences of the Artificial

Som Naidu

Monash University
Parkville, Victoria
Australia

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Editor's Note

The design of effective, efficient and engaging learning and teaching experiences is the product of synergies derived from knowledge about the technology, pedagogy and the subject matter. It includes knowledge about the affordances of each attribute, as well as knowledge that lie at the intersections of these three variables. More recently dubbed as technological pedagogical content knowledge by Mishra and Koehler, this is an idea that extends Lee Shulman's concept of pedagogical content knowledge to include knowledge about the technology (i.e., the media), and the content (i.e., subject matter that is to be learned and taught). At the heart of synergies derived from this kind of knowledge is design which is a science of the artificial, as opposed to a natural science. And this is about creating and orchestrating how productive learning and teaching experiences ought to be. The ideas that are articulated in this chapter will resonate with teachers and teacher educators as they search for ways to integrate ICTs in their teaching and learning activities.

Introduction

In his classic book "The Sciences of the Artificial", Herbert Simon differentiates between the natural sciences and the sciences of the artificial. He proposes that fields of scholarship such as *technology*, *education* and *design* comprise the sciences of the artificial, just as chemistry, physics and biology are regarded as sciences of the natural phenomena. The natural sciences (including social sciences) are areas of study that are concerned with defining the nature of things. They help to explain the world around us and things as they are (Simon, 1969, 132-133). The sciences of the artificial, on the other hand, include areas such as computing, engineering, architecture, and education and these disciplines are concerned with defining how things ought to be. A defining characteristic of the sciences of the artificial is *design*. This chapter explores the fields of *technology*, *education* and *design* (as sciences of the artificial) and discusses their separate as well as combined implications for the *design of learning and teaching experiences*.

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Technology

Traditionally, conceptions of technology especially in the educational arena conjure references to information and communications technology and especially those that are electronic in nature, such as computers, and communications devices including telephones, radio and televisions. A quick search of the Web however, reveals that technology means a lot more than just hardware and software accompaniments. The business dictionary defines technology as…

> the purposeful application of information in the design, production, and utilization of goods and services, and in the organization of human activities. Technology is generally divided into five categories:
>
> 1) *Tangible*: blueprints, models, operating manuals, prototypes;
> 2) *Intangible*: consultancy, problem-solving, and training methods;
> 3) *High*: entirely or almost entirely automated and intelligent technology that manipulates ever finer matter and ever powerful forces;
> 4) *Intermediate*: semi-automated partially intelligent technology that manipulates refined matter and medium level forces;
> 5) *Low*: labor-intensive technology that manipulates only coarse or gross matter and weaker forces.

(Retrieved from: http://www.businessdictionary.com/definition/technology.html)

Notice the reference in this definition to words such as "blueprints, models, and operating manuals" as well

as "consultancy, problem solving, and training methods". None of these would need to be a machinery of any kind. They refer to techniques and processes. Similarly, according to Wikipedia…

> The word technology refers to the making, modification, usage, and knowledge of tools, machines, *techniques*, crafts, *systems, and methods of organization*, in order to solve a problem, improve a pre-existing solution to a problem, achieve a goal, handle an applied input/output relation or perform a specific function. It can also refer to the collection of such tools, including machinery, modifications, arrangements and procedures...

(Retrieved from: http://en.wikipedia.org/wiki/Technology)

Notice in this definition of technology as well, reference to "systems, and methods of organization" and "arrangements and procedures". The point really is that technology is a lot more than machinery and hardware, and that much of it comes in the form of software. These can be in the form of *plans, processes, techniques and strategies*. Or as Mike Spector puts it "technology involves the practical application of knowledge for a purpose" (see Spector, 2012; 5).

Education

The Wikipedia defines…

> Education in its general sense [as] a form of learning in which knowledge, skills, and habits of a group of people are transferred from one generation to the next through teaching, training, research, or simply through auto-didacticism. Generally, it occurs through any experience that has a formative effect on the way one thinks, feels, or acts.

(Retrieved from: http://en.wikipedia.org/wiki/Education)

Education as a field of practice comprises the acts of teaching and learning. Learning has much to do with memory and cognition, and teaching has a lot to do with the design of the learning experiences so that desirable learning can take place. Neither one is sufficient on its own. Learning and teaching go hand in hand, and they are parts of the same educational transaction (see Spector, 2002).

"Education, like technology involves change in addition for being purposeful and specific to a subject matter domain" (see Spector, 2002; p. 7). It is true that learners can learn by themselves such as in the case of independent study (through self-study or auto-didacticism). But even in this case there is teaching going on. Some of this is designed in the learning resources one chooses to use, and some of it is provided by the learners themselves in the form of strategies they choose to use (such as note taking, concept mapping, summarizing and rehearsing) as part of their learning activities.

> "students in an environment where they want to learn and where they can naturally discover their true passions" (see Robinson, & Aronica, 2009, p. 238), and "great teachers have always understood that their real role is not to teach subjects but to teach students"

Learning is not learning if a formative shift in one's cognitive schema has not occurred. And teaching is not teaching if one has not learned. As Noel Pearson (an Australian Aboriginal Activist) bluntly put it, "if the student has not learned, the teacher has not taught" (2009, p. 35). But teaching is not simply about talking at students about a body of subject matter knowledge. If learners have not learned anything, then all a teacher may have done is 'talked' at them, or given them a "lecture".

Teaching is a lot more than that. It is about influencing one's cognitive schema with new knowledge and realizations and/or new approaches to viewing reality. It is about moving minds (see Laurillard, 2012). Teaching is about motivating students to want to learn (see Keller, 2008; Mathews, 2009). It is about placing "students in an environment where they want to learn and where they can naturally discover their true passions" (see Robinson, & Aronica, 2009, p. 238), and "great teachers have always understood that their real role is not to teach subjects but to teach students" (p. 249).

Design

Design is concerned with applying knowledge and intuition to come up with artefacts that have not been invented or applied yet. The act of designing begins

At the heart of learning and teaching is design. Effective, efficient and engaging learning and teaching is the result of good *learning experience design* which is a creative process. In the case of education generally, and learning and teaching more specifically, the principles for designing will have been derived from extensive study and investigation into human learning and cognition, the affordances of technology, knowledge of the learning and teaching context as well as best practices in teaching.

with an in-depth knowledge of core principles as well as a very thorough understanding of the context. Quite often a particular design is the outcome of the interactions between the design act and the issues and requirements of the context. Seen in this manner, design is a "situated act" (see Suwa, Gero, & Purcell, 2000, p. 235).

At the heart of learning and teaching is design. Effective, efficient and engaging learning and teaching is the result of good *learning experience design* which is a creative process. In the case of education generally, and learning and teaching more specifically, the principles for designing will have been derived from extensive study and investigation into human learning and cognition, the affordances of technology, knowledge of the learning and teaching context as well as best practices in teaching. Classic examples of notable learning experience designs are *problem-based learning* (Barrows, & Tamblyn, 1980), *scenario-based learning* (Clark, 2012; Naidu, Menon, Gunawardena, Lekamge, & Karunanayaka, 2007), and *case-based reasoning* (Kolodner, 1993).

Unlike the natural sciences, education generally, and teaching in particular, is best seen as a *design science* which has the aim of continuous quality improvement based on best practices (see Laurillard, 2012, p. 8). Education which includes learning and teaching are multivariate and complex processes. And unlike the natural sciences, investigations into most aspects of education, learning and teaching are not well suited for experimentation. Research and scholarship in learning and teaching is best achieved through critical reflection on practice. But this does not mean that experimental and/or quasi-experimental methods are unsuitable for the investigation of particular aspects of learning and teaching, and it certainly does not mean that investigations into learning and teaching can be any less rigorous than that which is acceptable in the natural sciences.

It suggests that investigations into aspects of learning and teaching are best accomplished with a range of strategies through naturalistic inquiry from the qualitative paradigm. A widely used such strategy is *design research* or *design-based research* (see Design-Based Research Collective, 2003; Nelson, 2013). Simply put, design-based research is about developing a design, building a model of the process based on that design, implementing it, and then collecting data on its performance, strengths and weaknesses using a wide range of data gathering techniques.

A classic example of this would be developing and implementing a program of curriculum reform or course design in a particular educational context. It would be meaningless to compare such an approach or model with another. Even if it were the same model with the same theoretical orientation, the context would be different. Comparisons of their efficiency and effectiveness would not be very meaningful. An ethnographic approach would be better suited to evaluating the impacts of such a process or program. And evaluations, as a form of research, if they are rigorously conducted can be very insightful and illuminating (see Patton, 2008).

In this manner, much of educational practice is design-based, and lends itself to design-based research. It incorporates building programs and implementing processes that are based on tried and tested principles and practices, and evaluating their impacts on stakeholders, systems and organizations based on a rich variety of perspectives, and with no less rigor than experimental methods (see Anderson, & Shattuck, 2012).

Implications for learning experience design

Learning and teaching are core components of most forms of educational practice. And like any form of educational practice, they are design-based activities. From self-study, to a didactic lecture, to group-based problem-based learning and role-play, some level of design is integral to any form of learning and teaching activity. In the case of a lecture, for instance, along with defining the focus and scope of the lecture, a

teacher needs to research and compile the subject matter content in a meaningful way. And also consider issues such as sequence and timing of the lecture, the audience and the ambience of the venue in order to ensure achievement of the goals of the lecture and ensure maximum impact.

The level of design increases in scope and intensity as the learning and teaching activity becomes more complex. A number of factors become relevant when this is the case. These include decisions that need to be made around the *scoping and selection of the subject matter content that needs to be taught*, its *delivery mode and technologies* that will be used, and the *pedagogical principles* that would drive the design of the learning and teaching experience including methods and strategies for the assessment of learning achievement and how feedback will be provided.

Decision making around all of these variables requires specialist knowledge about *technology*, *pedagogy* and the *subject matter content*. This is knowledge about the affordances of technology as well as the pedagogy for different kinds of subject matter content (Kennedy, 2015). Popularized as *technological pedagogical content knowledge* (TPCK) by Mishra and Koehler (2006), this is a concept that has its origins in Shulman's (1986) notion of *pedagogical content knowledge* (PCK) and it comprises knowledge that lies at the intersections of these three variables. Figure 1 seeks to capture these knowledge domains. These domains and their implications for the design of the students' learning experience are discussed in the remainder of this chapter.

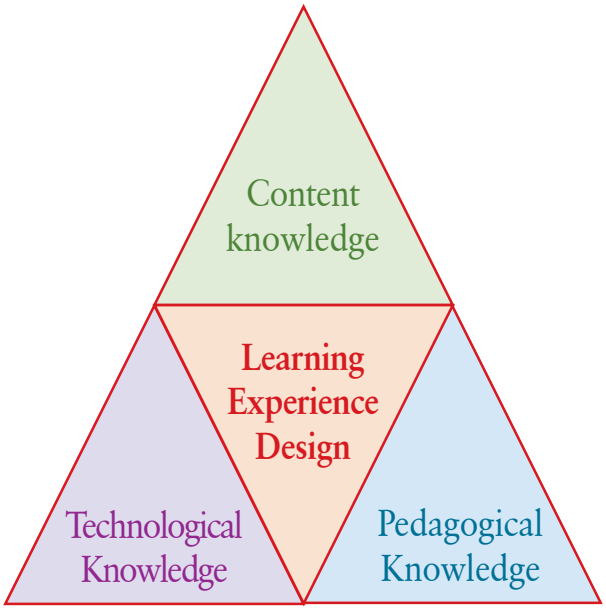

Figure 1. Implications for learning experience design

Technological knowledge

This is knowledge about delivery modes and the tools and technologies that are used in any educational delivery mode. Take for instance the contemporary lecture hall in face-to-face educational settings. In the more developed educational contexts, this is no longer just a room full of desks and chairs and a blackboard or whiteboard at the front of the room. The contemporary lecture hall might have mobile furniture and a suite of technologies to control sound and lighting in the room, and tools for the recording of a lecture and other deliberations in the room. It might also have facilities for twitter feeds in real time, and possibilities for various other forms of communication between and among students as well as students and the teacher. Without a solid grasp of how to operate these tools in this environment, troubleshoot and manage the deliberations there, a lot could go wrong with a straightforward lecture.

Contemporary distance education systems and online learning environments comprise the use of many more sophisticated tools and technologies from various forms of synchronous and asynchronous communications channels including multipoint audio and video conferencing, online learning management systems including synchronous and asynchronous discussion tools, and a range of widely accessible social media tools.

The distance education and the online learning and teaching environments offer far greater challenges and levels of complexity. Contemporary distance education systems and online learning environments comprise the use of many more sophisticated tools and technologies from various forms of synchronous and asynchronous communications channels including multipoint audio and video conferencing, online learning management systems including synchronous and asynchronous discussion tools, and a range of widely accessible social media tools. Contemporary learners not only have easy access to these tools and technologies but are very comfortable with using them frequently. Knowledge of how to use these technologies, troubleshoot them and help students use them effectively in their learning is an essential competency for any teacher (see Baggaley, 2012).

Decisions around their use have to do with choices about delivery modes and the mix and match of individual technologies in any mode. In fact the term "delivery" is inappropriate here as, except for perhaps the lecture format, teaching is no longer about "delivering" anything to anyone in complex educational settings. In such settings, the term delivery becomes an inadequate descriptor of what teaching is really about. Here *teaching is fundamentally about the design of student learning experiences*. The choice of mode in this case will have to do with how much of it is going to be one-on-one or group-based, and face-to-face, online, at a distance or in a combination of these modes.

The choice of mode in this case will have to do with how much of it is going to be one-on-one or group-based, and face-to-face, online, at a distance or in a combination of these modes.

Decisions around these issues will need to be aligned with organizational orientation and its educational philosophy. Organizations that purport to be distance education organizations, for instance, will very likely have the balance tipped in favor of more distance education provision, whereas conventional campus-based organizations will tip the balance in favor of more face-to-face educational offerings including the blending of various modes (see Baggaley, 2012; Naidu, 2010a).

How different modes might be used to "blend" one's approach will also depend on the purported organizational orientation, as well as a host of other factors including the level of study, the nature of the subject matter or skill that is being communicated, and the duration of the study. It might be possible, for instance in higher levels of study such as at the doctoral level, to have more of it carried out as private study and away from the campus, while first year undergraduate study in medicine and the engineering sciences requiring greater residential and perhaps one-on-one or small group-based and face-to-face contact because of their practical and hands-on components, will require more of it to be conducted in single and in group-based laboratory or practice-based settings.

The choice of individual technologies will also vary depending upon the existing infrastructure in an educational context, learners' and teachers' access to online and digital technologies as well as its purpose. For instance, despite the existence of infrastructure to support online and digital communications in an educational context, print may still be the ideal means for the communication of large amounts of reading material. And this may be so because of the portability of print and the flexibility it affords the learners in any context, developed or developing (see Naidu, 2010a).

Pedagogical knowledge

This comprises a deep level of understanding of principles about learning, teaching and cognition, how they work in different situations for different kinds of learners and with different kinds of subject matter. A partial or limited understanding of these principles would be insufficient, as it is one's understanding of these principles and how they interact that will drive the design of their approach to teaching as well as the design of their students' learning experience.

This comprises a deep level of understanding of principles about learning, teaching and cognition, how they work in different situations for different kinds of learners and with different kinds of subject matter.

This will include developing strong belief systems about learning, teaching and cognition that can be backed up with evidence from extant literature and practical experience. These belief systems could revolve around what one might think about particular approaches to cognition as well as the affordances of various technologies. For instance, how much structure and guidance and how much interaction or flexibility was going to be enough, with which group of learners, in which kinds of educational contexts, and with what kind of subject matter content or skill.

It is not possible to start to think about any form of teaching activity without having some view about factors to do with learning and cognition, no matter how transient. These factors include how a particular group of learners might like to approach their learning activities (see Kember, 2001), their pervasive learning styles (see Richardson, 2005), the nature of the subject matter content, and the time that might be available, both for teaching and for learning purposes.

There is a great deal of literature that sheds light on all of these factors (see Laurillard, 2012). Even the straightforward didactic lecture is probably influenced by one's belief that certain concepts have to be explained by subject matter experts, and students might actually expect that someone will explain it to them, and especially if they are reading or hearing about something for the first time (Chen, Bennett, & Maton, 2008; see also http://www.facultyfocus.com/articles/teaching-professor-blog/didnt-teach-learn/).

Different kinds of subject matter will require different kinds of approaches. And these approaches will be driven by different belief systems about learning and cognition. The development of higher order thinking, for instance, and the development of graduate attributes such as problem solving, critical thinking, interpersonal and group-based communications skills, collaborative working and team-building will require a different kind of approach to the lecture. These approaches will need to be scenario-based and problem-oriented. They will need to be learner and learning centered, not teacher or content-centered. And they will need to promote the idea of learning by doing, as opposed to learning by listening or watching (see Barrows, & Tamblyn, 1980; Naidu, 2004; 2008; 2010b; Schank, 1997).

How learning achievement will be assessed and feedback provided is a critical component of an understanding of pedagogical content knowledge (see Naidu, 2004). This will need to be aligned with the pedagogical model and the principles underpinning the approach to teaching, and its expected learning outcomes. If the learning outcomes are of a lower order such as remembering and recalling, then assessment of such learning outcomes might take the form of a closed book examination.

However, if the learning outcomes were of a higher order, such as the abilities to synthesize, evaluate and create, then the methods of assessment of such learning outcomes will have to be approached through a wide range of activities and outputs including artefacts such as project reports, reflective journals and portfolios, all of which are far better suited to ascertaining more than the understanding the subject matter content.

Subject matter knowledge

This is knowledge about the subject matter that is to be learned and taught. It comprises a thorough knowledge of the *facts, principles* and *procedures* of the body of the subject matter that learners will need to understand and be able to apply to different situations and contexts. Inadequate grasp of the subject matter, or not knowing where to source it, and how to communicate it to novice learners, pose some of the greatest challenge to teachers.

Decisions around the subject matter content will have to do with scope and coverage, its sequencing and synthesising for different levels and kinds of learners, and using different kinds of technologies in different educational contexts. Among the many theories and propositions for optimum ways of sequencing and synthesising subject matter content are those that have been articulated by David Merrill (see Merrill, 2002; Merrill, 2013), and Charles Reigeluth (see Reigeluth, 1992).

The five principles that underpin Merrill's proposals for sequencing and synthesising instruction and their implications for learning and teaching are as follows (see also Merrill, 2002; Merrill, 2013):

1. *Demonstration:* Proposes that learning is promoted when learners are observing a demonstration.
2. *Application:* Proposes that learning is promoted when learners are applying the new knowledge.
3. *Task:* Proposes that learning is promoted when learners engage in a task-centred instructional strategy.
4. *Activation:* Proposes that learning is promoted when learners are activating relevant prior knowledge or experience in order to complete assigned learning tasks.
5. *Integration:* Proposes that learning is promoted when learners are integrating their new knowledge into their everyday life.

At the heart of Reigeluth's proposals and suggestions for sequencing and synthesising instruction is the notion of "elaboration" which builds upon David Ausubel's work on the role of advance organisers in learning and teaching (see Ausubel, 2000), and Jerome Bruner's concept of the spiral curriculum (see Bruner, 1960). Reigeluth's elaboration theory suggests that teaching is most effective and efficient when it is organized in an increasing order of complexity where the simplest tasks and activities are introduced first and these are then followed up with increasingly more complex and complicated tasks and activities. In these conditions

and at all times, learners are building upon what has already been learned.

Reigeluth's elaboration theory comprises the following main steps:

1. *An elaborative sequence* which proposes a simple to complex ordering of concepts;
2. *Learning prerequisite sequences* which suggests the introduction of concepts in an order of increasing complexity;
3. *Summarising and synthesising* which recommends that there is built into this sequence, opportunities for summarising content already covered;
4. *Use of analogies and other cognitive strategies* which have the potential to provide structures for subsequent learning activities; and
5. *Providing opportunities for learner control* which will enable learners to customize learning that is best suited to their learning styles and approaches.

The first piece of instructional activity in this sequence is most critical as it seeks to *epitomize* and not just merely *summarise* the content that will follow. The proposition of elaboration theory is that this kind of sequencing of subject matter content has the greatest potential for developing stable cognitive structures for the development and retention of increasing levels of complexity in the subject matter knowledge.

Merrill's first principles of instruction and Reigeluth's elaboration theory are two of the most prominent perspectives on sequencing and synthesising instructional content. While the principles they articulate are generic and applicable in any educational setting, the technology used for mediation in the learning and teaching processes they articulate would vary for different kinds of learners, subject matter and educational context. In distance education and online educational settings, for instance, how the content is presented and mediated would differ from the way it might be dealt with in a face-to-face class (see Naidu, 2010a). This is never a constant phenomenon, as the tools and technologies available to teachers are, and will continue to be changing, both in the conventional classroom, and in the distance education and online world. In this regard, teachers will always have to be up skilling themselves in order to be effective and efficient, and making the most of the affordances of contemporary tools and technologies regardless of their educational context.

Concluding remarks

Great teaching is about designing a potent learning experience for the students where their learning is most *effective, efficient, engaging and enjoyable*. This kind of teaching requires careful thought to what will be taught and learned (i.e., the subject matter), how it will be taught and learned (i.e., its pedagogical approach), and what tools and technologies (i.e., technology), will be used by the teachers and students, as well as how much time will be spent on teaching and learning (see Kennedy, 2015). *Simply put, great teaching is when students can claim to have learned something.*

... as I have suggested throughout this chapter, this requires an in-depth understanding of not only the subject matter, but the pedagogy (i.e., the art and science of learning and teaching), and the technology, as well as knowledge that lies at the intersections of these variables.

And as I have suggested throughout this chapter, this requires an in-depth understanding of not only the subject matter, but the pedagogy (i.e., the art and science of learning and teaching), and the technology, as well as knowledge that lies at the intersections of these variables. This is what Mishra and Koehler (2006) have called *technological pedagogical content knowledge* (TPCK). Seen in this manner, *teaching is a design science* which requires careful thought and expertise not unlike that which is required for the design of roads, bridges and buildings or, for that matter, any such infrastructure or artefact. And teachers are *architects* and *choreographers* of this learning experience like directors of ensembles, or architects and engineers of roads, bridges and buildings.

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Author's Bio

Som Naidu, D.Litt. has spent much of his professional life in the higher education sector, in a variety of roles and in different jurisdications, to do with enhancing learning and teaching practices, curriculum design and development and online learning and teaching. Currently a Monash University Affiliate, most recently Dr. Naidu served as Associate Professor (Learning Transformations), at Swinburne University of Technology in Melbourne, Australia. From October 2008 to April 2013, he served as Associate Professor and Director of Teaching and Learning Quality Enhancement and Evaluation Services at Charles Sturt University. Prior to that he served 11 years at the University of Melbourne as Associate Professor of Educational Technology and Multimedia Education and Head of Research and Evaluation. Dr. Naidu earned PhD in Educational Technology (curriculum and instructional design and distance education) from Concordia University in Montreal, Canada, and received D.Litt. in 2014 from Open University of Sri Lanka. Dr. Naidu is current president of the Open and Distance Learning Association of Australia, and serves as Executive Editor of its journal – Distance Education.

Correspondence:

Som Naidu
Monash University
Parkville, Victoria
Australia, 3052
sommnaidu@gmail.com; somaiya.naidu@monash.edu.au.

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