

## Chapter 2

# A Paradigm Shifts and User Interface Design Models

*A new type of thinking is essential if mankind to survive and move toward higher levels.*

Albert Einstein

**Abstract** A paradigm shifts, according to Thomas Kuhn, is a fundamental change in the basic concepts and experimental practices of a scientific discipline. Do paradigm shifts change the design models according to changes in education? The goal of this chapter is to present a comprehensive description of linear, systems and meta-systems thinking approaches. Its scope is limited to the instructional design models and principles of user interface design. The chapter deeply explores the contrasts, connections, and influences from the realm of thinking to the real.

**Keywords** Linear thinking • Systemic thinking • Metasystem thinking

### 2.1 Introduction

The term ‘design’ may be associated with the thinking’ patterns. According to Visser (2006), design thinking is the design-specific cognitive activities that designers apply during the process of designing. But, can be only the cognitive activities important for instructional design? Let us analyse this idea starting from the paradigm shifts in education. The term ‘paradigm shift’, coined by the Thomas Kuhn, defines a fundamental change in the basic concepts and experimental practice of a scientific discipline. In the case of the digital textbook theory and design, the paradigm shifts could be associated with education 1.0, education 2.0 and education 3.0 and, therefore, with changes in the intellectual inquiry noted in the educational technology as well as in philosophy, psychology, cybernetics, and neuroscience and knowledge management.

Hairston (1982, pp. 78–80) notes that to understand the nature of the paradigm shift in textbooks’ development is important to look at the principal features of that educational paradigm that has been the basis of the composition teaching for several decades or hundreds of years, taking into account that textbooks’ police and content

change slowly. Publishers want to keep what sells, and they tend to direct the appeals of their books to what they believe the average composition teacher wants, not to what those in the vanguard of the profession would like to have. In turn, for them is better to accept the digitalised version of printed textbook than to implement a new interactive technology, even this technology is better for learning.

Nevertheless, the big changes in textbook theory and design are under way. Following the patterns that Kuhn describes in his theory, the first response to crisis in education has been to improvise the individualised learning through programmed instruction. Among the first response were teaching machine and programed textbook, which sprang up about 50–70 years ago to give first aid to teachers who seemed unable to teach students within the traditional paradigm.

However, the first attempt has not solved the problem. Another ad hoc ‘problem solving’ within self-directed learning and local networking in classroom, but, as was it noted by Hairston (1982, p. 82), it has faded from the scene along with the computer-assisted instruction. In plus, network and cloud computing, nano-education and big data, common for education 3.0, are the actual ad hoc measure that paradigm is only a temporally palliative for problems related on sustainable education. Not all have solved the crisis of education. What are the reasons?

In our point of view, any paradigm is only the background for solving common controversies, problems or issue. More important is to develop and to implement a theory with well-defined principles that will correlate with the paradigm. What we have today in user interface design of digital textbooks is inexplicable, on the one hand, education 3.0 and on the other hand, design principles based on learning theories for XV–XIX century.

Among the solutions of reconceptualisation the user interface design of digital textbooks, one of them is design thinking—a mindset as the strategy of innovation in learning. However, in this case the user interface design must be updated at the level of accepted paradigm. What we have today? As was noted by Teal (2010, p. 295), most students appear to undertake the process of design in a more or less linear fashion. This practice is exemplified in the oft heard phrase, ‘I would have done “X” if I’d only had enough time ...’, which is frequently employed to explain why site development, detailing, materials—in short, things associated with a ‘finished’ building—are left unattended. Could be the linear design thinking so problematic for learning?

Systems thinking is, according to Richmond (1994) ‘the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure’. The author find many differences which allow to say that system thinking is not similar with General Systems Theory, not it is System analyses, Chaos Theory, Dissipative Structures, Operations Research, Decision Analysis, or Systems’ Dynamics. Thus, systems thinking enable to develop special thinking skills, characterised by the term ‘bi-focal’. People embracing systems thinking filters can see both the forest and the tree in three ways: system as cause thinking, closed-loop thinking and operational thinking. The most important thing of this theory is that operational thinking viewed with the framework of system dynamics.

There is a widespread though controversial belief about the fact that digital textbooks design is shaped according to the humans' thinking paradigms regarding the artificial systems. Perhaps more importantly, the pre-eminence of the work perpetuates the criteria, which asserts that world produced only a limited number of thinking patterns—hence a competition for an affordable digital textbook user interface design really exists. Does it mean that design thinking models are most at the philosophical or theoretical stakes, therefore, the instructional designers are not able to use them? Or, maybe, the digital textbooks are only the youngest brothers of the printed textbooks and, therefore, the user interface design is not an issue?

## 2.2 User Interfaces Issues in Digital Textbooks Use and Development

Human thinking paradigm is a common way to understand user interfaces patterns in digital textbooks use and development. Once we believe that competence is the power of the adaptive living in the actual world, the user interface design should allow developing digital skills, like digital reading, listening online or sharing content. Does these ways are the best to replace printed textbooks with digital versions? From the one hand, research has shown that students understand text less when they read on computers.

When reading on screens, for example, people seem to reflexively skim the surface of texts in search of specific information, rather than dive in deeply in order to draw inferences, construct complex arguments, or make connections to their own experiences. Research has also found that students, when reading digitally, tend to discard familiar print-based strategies for boosting comprehension (Montuori [2012](#)).

Listening online is a good way to learn, for example, a foreign language. Instead of the printed textbooks, digital textbooks may offer digital listening, reading and vocabulary practice. Audio textbooks for music education may include audio recording of famous artists as well as practical exercises. However, user interfaces of digital textbooks could allow students to assessable own textbooks, including own audio recordings or video. These are two different approaches: teacher centered and learner—centered. It is more than rationale to combine both approaches within learning, but there are two ways: *reproductive learning* and *productive learning*. Thus,

Reproductive Learning is an umbrella term for a form of education based on rote memorization and reproduction of existing knowledge. It reproduces the content, process, social structures, power relations, and individuals that conform to what are perceived to be societal needs and norms, mostly derived from the need to train workers at various levels of expertise. It is often the result if not the actual goal of educational approaches centered on assessment, and where the acquisition of existing information and conceptual frameworks is central. The learner and his/her values, experience, affect, and ultimately identity are not included in the learning process. Creativity and, therefore, the original generation and application of information and conceptual frameworks are not valued (Montuori [2012](#), p. 2838)

Reproductive learning is about memorization. Therefore, both those who use teacher-centered approached with different levels of achievement and those who do not go beyond simple instructions like *memorise this* (in a teacher-centered learning environment), are right. That is not to claim that students who are attain classrooms only use simple instructions. They may memorise some things involuntary or voluntary within computer-based assessment environment.

Productive learning is about solving problem with insight. Therefore,

Productive Learning is learning on the basis of productive activity in social “serious situations”, learning on the basis of experience, of being able to achieve something important, both for oneself and one’s environment. Thus, young people feel themselves to be important and valuable members of society and not simply reduced to the status of a school pupil. Productive Learning begins with activity i.e. learning is itself a product gained by experience of productive activity and young people acquire this with the assistance of educationalists (INNEPS 2016, p. 1)

For decades, educational research indicates that learning is equal to memorisation. Education 3.0 changes this vision in favour of productive learning. Which models: productive or reproductive learning, are required for an affordable user interfaces of digital textbooks? Recently, the validity of the dichotomy between reproductive and productive learning has been questioned by the results of both qualitative and quantitative research, which demonstrated that successful learning depends on problem that students have or on issue that is proposed to be solved as well as what IQ is required or how many information and energy is required.

‘User interface design of digital textbook means display mode and pattern of digital textbook’s content and multimedia resource. The user interface design will not facilitate better easy operation if it does not meet users’ needs’ (Liu et al. 2014, p. 130). But, recently research demonstrated that designers could think about digital communication in qualitatively new way. For instance, following the idea of Pandeia Communications, billions of peoples around the world will be connected online using a voice call. Therefore, soon everybody will be connected to Internet via a future phone or Android device, even they don’t have a digital device. In sum, there are five communications patterns in design of user interfaces: text (message), picture (graphic), audio (voice), video (TV, multimedia), and touch (multi-touch).

The perception of affordance in user interface design for learning has been questioned by a phenomenon, which is generally referred to the paradox of the design thinking as a solution for innovation. This paradox introduces two stereotypes: *universal design for learning* and *personalised design for learning* (Karsvall 2002). The universal design aims to improve and optimize teaching and learning for all peoples based on *representation* (e.g. present information and content in different ways); *engagement* (e.g. stimulate interest and motivation for learning); *action and representation* (e.g. differentiate the ways that students can express what they know). This is a case of flexible curriculum and setting up the aims, objectives and methods, which work for everyone so that each student can progress.

The second stereotype introduces the term ‘personalised design’ and is principally based on the study how learning parts can be adapted to students’ progress. However, in practice, it was developed some prototypes patterns, defined by

Karsvall (2002, p. 1), as neutral, extrovert and introvert design. The neutral design is equivalent to the original prototype: it display variations of saturated hues in greens, blues, reds, black and white and users both rounded and squared shapes. The extrovert prototype provides higher contrast between interactive elements and even more saturated red, yellow and blue hues as well as darken inactive areas. The introvert design was accordingly given lower contrasts and de-saturated colours in white, green and blue. These two stereotypes are incompatible as taken together they seem to suggest that only rote learning or active learning based on psycho-physiological characteristics of students leads to academic success.

The concept of *user interface design* is central to behavioural, cognitivist and constructivist approaches. Behavioural approach is more related on designing programmed textbooks, but cognitivist—on designing multimedia and interactive textbooks. Almost, the user interfaces designing multimedia interactive textbooks for learning is Instructional Systems Design models. Usually these models describe the principles either Merrill or Gagne theories, or provide an individual model, like ADDIE, Dick and Carey, Morrison, Ross and Kemp and others. This is why the requirements of how to generate data on screen are very different.

Moreover, required processing, analysing, synthesis and communication actions by students, as well as planning and development of instructional objectives by teachers on the base on provided information on screen presents a variety of challenges for designers of the digital textbooks. There are one big issue: abstract data. Thus, abstract data could be presented as metadata, structured information, multimedia, audio or graphic representation, or/and knowledge for feedback. There are multiple ways. One way is a user interface in which the immediate feedback ‘follows’ the content within tasks designed for individualised learning in order to make the provided content more understandable. The other way is user interface in which information presented on the screen serve only as metadata for personalised learning. The third way is the user interface, which present strictly individualised content, adapted to user’s progress.

Consider, for example, that user interface design models evolves according to human thinking paradigms. Thus, Dick and Carey model was developed in 1990, during the second phase of the digital revolution. The model describes the design process in ten steps: identification the instructional aim, analysing the instructional aim, analysing the learner and the content, writing performance objectives, development of assessment methods, development of instructional strategy, development of instructional methods, design and development of formative assessment, control of programme’ content and summative assessment.

The model of Morrison, Ross and Kemp was developed in 2004 (during the intermediary period between second and third phase!). This model describes the user interface design according to ADDIE scheme. Instead of the instructional aim, it is proposed to identify the *instructional problem* through evaluation of needs, analysing of aim, and evaluation of performance. The phase of analysing the instructional aim is changing with analysing of students and required tasks (general characteristics, competence, learning style, analysing of context). Moreover, writing the performance objectives, according to previous model, were changes in favour of

instructional objectives and performance matrix. The stage ‘development of instructional objectives’ is completed with the dimension, succession, frequencies of frames and instructional strategies. Assessment and control is completed with testing of knowledge, abilities, behavior and attitude.

In sum, all ADDIE instructional design models neglect the differences between the author vision of design’ elements and the reader’s perception. This subject has been discussed all times particularly because of the concerns that it raises as teacher, student and content, on one hand, are often wrongly used interchangeably. On other hand, it is neglected the changing context for learning. Thus, in the concept of education 3.0 students prefer to share knowledge instead of getting knowledge; to access the on-line courses in order to explore new subjects instead of listening lessons in classroom; ‘external control’ instead of formative/summative assessment.

Does above-mentioned features indicate at evolution of user interface design? In the classic model of education, text and picture communicates clearly the information to student through printed interfaces. Numerous design thinkers note that user interfaces of the student’s textbook should differs from the user interface of teacher’s textbook. Only teacher is able to establish connection between textbook and students’ needs in learning.

An ideal visualisation should not only communicate clearly, but also stimulate viewer’s engagement and gain attention to some elements (Viegas and Wattenberg 2011). What is threatening about emerging technologies are potential scenarios of life, according to scientific transhumanism, taking over the world, and bringing both humanism and trans-humanism approached into design of interfaces for the un-existed world. This approach displays abstract instead of real knowledge and without to develop any skills and attitudes.

In theory and practice, there are multiple ways how to design user interface design for better engagement in learning. However, all this ways are suitable within one specific period, and there are not only one unique way for all periods. That is why, for instructional designers and publishers of the first digital textbooks to believe that learning is both reproductive and productive is fine as long as they don’t need to develop textbooks’ models beyond parameters of the digitised version of traditional school textbooks for sustainable education. This is more than learner-centered learning environments and relate on learning philosophy.

The postmodernism philosophy requires that learners will explore artifacts and patterns from the real world and, therefore, that learner to be motivated enough to think about own thinking and how to develop own abilities. On the other hand, the rapid digitalisation of the educational systems requires that learner to become a lifelong learner in order to be able to explore different cultures and diversity of learning environments for the best decisions regarding the sustainable development. Therefore, understanding the specific characteristic of the period in which user interface will be used is the best way in design affordable textbooks.

Each paradigm of design has had its day. The paradigm of digital textbook changed the understanding of learning forever in three steps: linear, systems and metasystems. Thus, now learning can be understood well starting from the mindset of the human paradigm. For example, the humanistic paradigm has been the

common belief for ages, but now Newtonian physics is at a loss when it needs to explain the quantum energy of thinking. Moreover, learner is not only human, but also a (meta)cognitive and affective system. Humans are “connected” through (meta)patterns bridges with all objects and subjects of real and virtual world. In brief, the user interface design of digital textbooks should be a real project aims to develop a well-defined learning mechanism.

## 2.3 Linear Thinking: Direct and Branching Styles

From the perspectives of changing paradigm of learning within digital revolution, ‘linear thinking’ is related to step-by-step progression when knowledge is assimilated in small steps. The learner must follow the ‘path’ presented by the programmer, however the learner using a programmed text may deviate from the path set down by the programmer by looking back in the program or looking ahead. One of the first example of linear thinking refers on user interface design of teaching machines. As was noted by Eigen (1962, p. 453):

a teaching machine presents an ordered sequence of instruction to the learner one frame at a time. After responding to a stimulus frame, the learner’s answer is immediately confirmed or corrected. The learner then proceed to the next frame; he is prevented from changing his previous answer or going back in the program. In a horizontal programmed text, succeeding frames appear on alternative pages. The learner write his answer to the frame either in the program booklet or on a separate answer sheet. He then turns the page, and the correct response is revealed along with the next stimulus frame. A horizontal text is read from the front of the book to the back, across the page, at one level. After completing the top level, the learner read across the text at the next lower level. This procedure is continued until the either text has been read. <...> Vertical programmed text are read from the top of the page to the bottom. The number of pages appeared on one page may vary from one to ten or twelve. A mask or slider is used with this mode of presentation.

For over 50 years, linear design of digital textbooks has embarked on numerous educational projects, but the obtained results are controversial. In brief, the linear designers prefer to understand learning as a stimulus-response or as a stimulus-response-reinforced associations, which allow developing a new behavior. During learning it is involved the dependent and independent variables. Thus, the dependent variable is a change in behavior that are observable and tangible. Instead, the independent variable is the consequence of behavior.

Smith and Smith (1966) have wrote, that learning is more than the open loop forming of new stimulus-response associations. Learning is a process of reorganization of sensory activity within a closed loop, or pattern, which is a process of reorganization of sensory feedback within a closed loop, or pattern, which increases the learner’s level of control over his own behavior and the stimuli in his environment. Therefore, for these authors the learning is space-organized rather than time-organized activity, organised from simple to complex and it is dependent on



the behavioural objectives and on design principles of the learning situation, especially the techniques and the instruments of education.

When learning is a space—organized activity, the school textbooks should follow curricula based on instructional (or behavioural) objectives. The objectives are realisable through individualized instruction with active practice and frequent feedback to students. For these objectives, in school textbooks should be included a simple-to-complex sequencing of content, criterion-referencing testing, self-pacing, mastery learning and much more. However, the linear designed content of textbooks is the fashion for Skinner's programmed textbooks.

Let us analyse deeper the linear thinking design of the programed textbook. A programmed textbook is a special designed program in the form of a textbook, which in addition to instructional material provides schemas of learning including reading/listening and control of knowledge assimilation. The principles of programmed textbooks are clear learning objectives, small steps, logical sequence, active responding, and immediate feedback, drill and practice and stimulus fading. However, instead of the well-defined principals of reinforced learning, the lessons in computer classrooms were bored. What are the reasons?

*Linear thinking* is related to instructional design approach. The term 'instructional design' defines a technology for the development of learning experiences and environment, which promote the acquisition of specific knowledge and skills by students. On the other hand, the term '*instructional design*' defines the process of planning instruction, delivering instruction and assessing student in the classroom and a form of complex problem solving (Handani et al. 2011, pp. 1–2). However, this approach is described by a behavior-oriented model which insists that students have fixed abilities be learned.

There are two possible ways: direct style and branching style. Philosophically, according to Skinner's theory, the people learn better through direct observation using own senses and learning is based on tangible, observable and repeatable factors. The learning outcomes can be observed and recorded. After the instruction period (e.g. a semester), the learner should demonstrates a new behavior. How to do this with so various unconnected concepts proposed through curriculum, and various textbooks' design for one level students? The fact that students cannot learn science only in a computer class is an issue, which can be solved by re-conceptualisation of curricula, as well as of the setup of the textbook design.

From other point of view, linear thinking is a way of linear programing and, therefore, correlates with the first phase of the digital revolution. This phase relates both on *visual thinking*, e.g. idea-sketching, seeing, and imagining and *audiovisual thinking* (Schlesinger and Waelde 2011; Tchulkina and Garbar 2016; Flynn 2016). On other hand, linear thinking is associated with classical instructional design models with teacher-centered learning environment, even it was started the research in mathematics.

In the context of these ideas, the main concepts methodology within user interface design have shown to be lacking. Researchers and practitioners, working in interdisciplinary area of pedagogy, rethink digital textbook design on an expanded basic in line with sustainable education (Hjorth and Bagheri 2006;



Bosch and Nguyen 2016; Ha et al. 2016). Thus, as was noted by Ha et al. (2016, p. 1), development efforts through the traditional approach of linear thinking with tends to solve immediate (visible) problems in isolation without an understanding of the local contexts and participation of direct beneficiaries and related stakeholders that have posed many flaws, leading to failures and counterproductive outcomes.

The methodology of learning is simple: students read the content on screen and answer questions. However, the content should be read from beginning to end and all students should follow the same objectives. It is expected that all students are ‘linear thinkers’, i.e. have the capacity to proceed information in a sequential manner. The didactic process is predictable by instructional objectives, small frames on screen, questions, answers and guidelines. This model is not the best for the actual students who understand media in other way, not as a text or image in book or textbook but as the bound screens up with in complex ways and patterns.

In linear design the content “takes” the learner in a positive progress, which starts only with positive feedback, and then works through problem solving, understanding the concepts and reinforcement the results. This means that the event *A* (cause) leads to event *B* (effect), which leads to *C*, then leads to *D* etc., and when each step is guided by well-defined objectives. On a user interface can be seen the Stimulus 1 ( $S_1$ ) that offer all conditions for Stimulus 2 ( $S_2$ ) etc.

Various learning scenarios prove the efficiency of linear thinking. The first benefits are *memory improvement* and *second language acquisition*. However, these benefits cannot be archived through simple mechanisation of education. The “mechanization of education”, as was observed by Skinner (1965), leads only to development of the computer-based teaching machine and of the mechanical teachers. But, “to automate education with mechanical teachers is like automating banking with mechanical tellers and bookkeepers” (p. 5).

Furthermore, Skinner (1965) observed that students might learn without teaching, but also, that only a teacher arranges conditions under which students learn more rapidly and effectively. The teacher begins with whatever behavior the student brings to the instructional situation; by selective reinforcement, he changes that behavior so that a given terminal performance is more and more closely approximated. The experimental analysis of behavior has more to contribute to a *technology of education*. This model describes *instrumental conditioning*. It was expected that the students’ behavior can conveniently be mediated by mechanical devices when machines present material and differentially reinforce his responses.

Any practical application of knowledge about learning theory is, of course, *pedagogy*. However, according to linear thinking approach the pedagogy describes only a technique of processing a stimulus *S* and getting answer *R* within the provided content. Therefore, learning is distancing from the real *performance* of the learner. That is why; the linear thinking in design of digital textbook was changed through time by multiple ideas:

- to find better teachers;
- to set up model schools, staffed by model teachers;

- to simplify what is to be learned; to reorganize what is to be learned;
- to improve presentation techniques;
- to establish multiply contacts between teacher and students;
- to expand the educational system from local system to global network of school
- to raise educational standards.

It is the time to re-think user interface design of digital textbooks. The task of the teacher is to improve the students' skills. Nevertheless, whose of the thinking models is attributed this task? Skinner (1965, p. 15) wrote that mostly programmed instruction has been called "Socratic", because of small steps and leading through an argument with verbal prompts. The second way is Comenius who advocated breaking material into a large number of small steps, arranged in a plausible genetic order. However, these are not enough because the student should not proceed until will fully motivated to learn at a given stage.

Advocates of linear thinking (e.g. Benjamin 1988, p. 708) prove that student's success could be maximized and that errors could be kept to a near zero level. To ensure this kind of learning, the material had to be organized in a coherent fashion, building a response repertoire, step by tiny step. One of the example on digital screen is *programmed English*, presented by Joyce et al. (2000, p. 333).

1. Words are divided into classes. We  
call the largest class nouns. Nouns are  
a class of \_\_\_\_\_. words
2. In English the class of words called  
*nouns* is larger than all the other  
\_\_\_\_\_ of words combined classes

The problem is that until recently the most people had learn in a linear fashion, and, therefore, follows yet the linear patterns for own living. A linear pattern learning is said to exist when the initial and final points examined form a straight line. Thus, for them the learning starts with positive results from primary school and proceeds straight across to the high school to University. During teaching, the teacher fellows the curricula, starting from beginning and moving in a straight line to the end. He/she uses the textbook and presentation on screen. Screen is used for reading core ideas of content, writing in a logical manner, from simple to complex.

In a linear fashion, a didaktik problem is easy to be solved. All of the didaktik 'things', like the context for learning, content, environment, and instructional objectives are together. Nevertheless, this is not a holistic approach of learning, but only a linear thinking about how to design learning. People understand dimensions, consistence and hierarchy of instructional frames differently. In fact, linear thinking designers believe that they know how to solve problems of today learning, but in reality do not know how to design user interface design. There are many reasons.

Some students have good memory, and some not. Some students are able to ‘mentally divide’ problems in frames, and some not. Other students need to write all frames on a digital screen in a copybook to understand the order of solving the provided tasks. They may need a tool able ‘to translate’ information into his/her *mode of perception*. Explaining problem solving on digital screen in a linear fashion does not help with this issue.

Branching programming or branching style of the linear thinking is a technique of learning with computer. On screen, each frame presents more text than the average linear frame. After reading, the user responds to a question, usually in a multiple-option format and may receive corrective feedback in order to remediate the learner’s misconceptions or gaps in understanding. There are multiple approaches of branching programming. One of them is simple branching or *intrinsic programming*. The intrinsic program ‘build’ the necessary alternatives into the program itself. Gilman (1972, p. 65) with reference to Crowder (1963), summarise the process of intrinsic programming as follows:

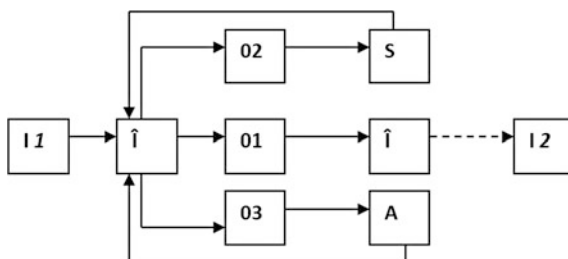
The student is given a sort description of the material to be learned, following by a multiply-choice question designed to test the point just discussed. The basic intrinsic programming technique, then, amounts to nothing more than the inclusion of multiply-choice questions in relatively conventional expository text and the use of these questions to continually check the students’ progress through the material and to finish specific remedial material as it is required.

Unlike Skinner, Crowder’s user interfaces includes the frame for communication between user and author through immediate feedback. The linear sequence includes frames with more text for reading and require response to an adjunct question, provided usually is a multiple-option format. The feedback corrective. Thus, if the student makes a correct response, the program asserts the reasons why the response is correct and moves on to new material. However, if the response is incorrect, the program inform the user that an error was made and then branches the user back to the previous frame for another attempt. One version of Crowder’s schema is presented in Fig. 2.1.

Differences between Skinner’s and Crowder’s approach of linear thinking are in Table 2.1.


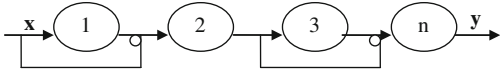
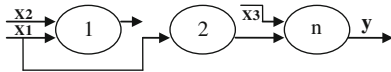
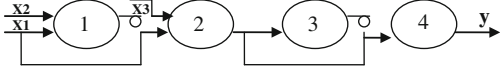
The model of full branching is *adaptive programming*. Gilman (1972, p. 65) with reference to Crowder (1963) note that adaptive programming is extrinsic, because some external device assists in the control of the program. These programs permit analyse of a student response and the arrangement of the future learning contingent

**Fig. 2.1** Crowder’s schema to design the branching program



**Table 2.1** Skinner’s instead of Crowder’s approach of linear thinking

	Skinner	Crowder
Content	Small frames	Large frames
Feedback	Positive/negative learning	Corrective learning
Level of abilities	Lower-ability user	Higher-ability user

Graphical representation of structures	The name of structures
	<i>simple structure</i>
	<i>simple structure with output</i>
	<i>complex structure</i>
	<i>complex structure with outcomes</i>

**Fig. 2.2** The graphical representation of logical—structural scgemas

in the light of students’ characteristics and student’s response. In our day, when personal computers and Internet have reshaped media, the educational technology is changing also. There are multiple examples of adaptive textbooks with personalised content, whiteboards and projection screens. One of this way is using of the logical—structural schemas, as it is presented in Fig. 2.2.

Indeed, the technology promises to offer a new way for learning, but until now didn’t solve the problem how to engage all students in adaptive learning. As was written in New Scientist (2014), adaptive learning is struggling to provide understanding of subjects for middle students, while faster learners can surge ahead without getting the bored learning at computer.

Develop the design principles for interactive content. In their opinion, the psychological principles involves the nature of memory and mental structures, the nature of conscious and unconscious attention, response time and time to learn, the nature of errors, learning and problem solving strategies, the role of language in cognition, encoding processes and gulfs of understanding. However, the graphic design principles focus on issues of composition: layout, weight, color, positive/negative space and balance; color: color combinations, colored type and the psychology of color; type: typeface, type styles, legibility and the psychology of type; and graphics: graphic elements, color, placement, and integration into an overall design.

## 2.4 Systems Thinking and Systems Dynamics

Since 1970 schools began acquiring computers and use them for instruction, drill and practice, record keeping and other things. Since 1900 textbooks have migrated to digital and tablets. However, in both cases educational software programs were developed on the base on linear and systems thinking. According to systems thinking approach, the learning, on the bases of instructional system design, follows a well-established algorithmic model. The core model is ADDIE (where A-analyses, D-design, D-development, I-Implementation, and E-evaluation). Therefore, instructional design model based on systems thinking helps designers to make sense of abstract learning theory and enable real applications for instruction and assessment.

Until now, it was developed many instructional systems, including educational software, eBook/iBook, digital textbooks and others. Instead these systems embody the instructional objectives and are developed on the base on ADDIE model, theirs effectiveness for learning is not proved with the empirical research. Moreover, the holistic approach in the systems thinking means to derive understanding of parts from the behavior and proprieties of wholes rather that derive the behavior and proprieties of wholes from those of their parts. When holistic approach is integrated within the ADDIE model, the results are not better. What are the reasons?

First, in rapidly changing paradigms. Second, in the development of new concepts related on systems theory, like feedback, system, learning process, learning objects etc. Thus, the design patterns of the multimedia/interactive/adaptive textbooks come from the systems theory. However, with the extensive application of artificial intelligence and cognitive theory it was developed new tools, like *cognitive tutor*. But, those seeking to understand the meaning and the importance of the cognitive tutor for learning in a diversity of environments, first is confused by a diverse of the terminological terms associated with other terms, e.g. computer-assisted instruction, computer based education, computer based instruction, computer-enriched instruction, computer managed instruction, organisational learning and others.

In the actual textbook theory, 'systems thinking' is connected with thinking in complexity, in which the systems' parts have interrelated and worked over time within the dynamic and flexible context. In brief, all elements are working together to enhance the instructional/learning/assessment processes as well as all students in the learning process. All processes are managed at the level of metasystems. In a certain sense, it can be said that systems thinking is as old as educational philosophy if this is an equivalent to controllable activities and rational actions. In all other cases, when the student learns to grow (as a child, as a specialist, as a professional etc.).

Systems thinking has used in education and, therefore, in user interface design of school textbook before the concept of system was described in the General System Theory (Von Bertalanffy 1972a, b) and it was formalised the notions of feedback (Wiener 1948). For example, the *Orbis* textbook, originally published by Comenius

in 1648, includes table of context and content according to a program, including 150 pictures. Such textbook attempts youngs in learning more effectively than grammatical handbooks. Indeed, the pictorial mode within the system thinking ‘holds’ together table of contents and content. This is the simplest and the most effective model of systems thinking, used until today.

Nevertheless, systems can be closed or/and open. The closed system is an isolated system, not interacting with an environment. The equivalent of the closed system for education is the pedagogical system. Each of the pedagogical systems is an artificial designed system, which provide the abstracted content for learning not related with an environment issues, e.g. sustainable development. Frick (1991) observes that telecommunication technologies make the educational system much more open and flexible and estimates that a variety of “virtual teachers” and educational resources can be used every time and everywhere. Thus, the actual educational system archives new features, which are more or less focused on openness.

But, according to theory an open system changes its behavior in response to conditions outside its boundaries. Therefore, in an open educational system, learning occurs in more complex and changeable learning environments than in all artificially designed pedagogical closed systems. One attempt to understand the complexity of learning, and therefore, the design of real learning environment is the *Bronfenbrenner’s Ecological System Theory* (Bronfenbrenner 1994, p. 38), based on two postulates:

- human development takes places through processes of progressively more complex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate environment;
- the form, power, content and direction of the proximal processes effecting development vary systematically as a joint function of the characteristic of the developing person; of the environment – both immediate and more remote in which the processes are taking places, and the nature of the development outcomes under consideration.

The other attempt is to use the concept of *systems dynamics* (Angerhofer and Angelide 2016) to solve real problems through understanding the nonlinear behavior of complex systems over time using stocks, flows, internal feedback loops, and time delays. However, in reality systems thinkers are more comfortable when can integrate new and old knowledge in a systematic way. They are impatient with step-by-step instructions, but prefer to divide learning blocks into ‘bigger steps’, to follows instructional objectives and, for understanding, to add formative assessment during each steps (Sadler 1989). At the final stage, they prefer summative assessment or testing. In many cases, systems thinkers require linear thinking methodologies for problem-solving, especially algorithms.

In user interface design of digital textbook the system(s) approach is valued through *Instructional System Design* or *System Design*, defining the process of designing and developing efficient instructional courses or instructional materials to acquiring knowledge or skills. Instructional designers, trained to use a systematic approach to designing new instructional systems or to improving already existing systems, use Instructional System Design approach. Therefore, there are many instructional systems models.

According to Dick et al. (2001, p. 18), the basic components of systematically designed instruction are learning activities packages and modules. Thus,

A module is usually a self-instructional printed unit of instruction that has an integrated theme, provides students with information needed to acquire and assess specified knowledge and skills, and serves as one component of a total curriculum.<...>. Systematically designed instruction require learner to interact with the instructional material rather than simply allowing them to read the material passively. The learners are asked to perform various types of learning tasks and receive feedback on that performance. Some type of testing strategy informs the learners whether they achieved mastery of the content and what they should do, if not.

The most important elements are language, layout, and design of content. The size, color, and placement of each element ‘work together’, forming a holistic whole for perception. Instead of printed content, the digital content may include *variables*, like text, audio, and video messages. ‘System variables such as interactivity and clear audio and video transmission positively influenced perceived learning and satisfaction’ (Hackman and Walker 1990). For this record, the user interfaces of digital textbooks should be appropriate to those *design styles* and *user interfaces* that students prefer. A consistent content with a clear hierarchy enables students to focus on the most important things. Therefore, the good interfaces of digital textbook speak to the student; even his/her actions are right, wrong or misunderstood.

Moreover, visual, audio cues or simple messaging informs show the user whether his or her actions have led to the expected results. In case of the mistakes, the instructional system informs the student by showing what was wrong and how to prevent the error from occurring again. It is important to reward students within teaching situations with positive feedback or, at least, writing in a positive way. All user interfaces require copywriting. The information is provided in conversational form with clear and concise labels for actions. User interfaces require some level of copywriting. Keep things conversational, not sensational. Provide clear and concise labels for actions and keep your messaging simple. Your users will appreciate it, because they won’t hear you—they will hear themselves and/or their peers.

While “linear thinking forces use to see one thing at a time, and to progress to whatever is next, which will in turn lead to more” (Risku and Harding 2013), systems thinking for centuries was overlooked. As was noted by Lazanski (2010) systems thinking emphasizes looking at wholes rather than parts, and addresses the role of interconnections. It is a circular and focused on closed interdependences. It has precise set of rules that reduced the ambiguities and miscommunications that can crop up when we talk with others about complex issues. It offers causal loop diagrams, which are rich in implications and insight. The modern systems thinking principles are:

- the big picture.
- long term, short term perspectives.



- measurable and no measurable data.
- dynamic, complex and interdependent.
- we are a part of system.

In the opinion of Lazanski (2010, pp. 293–295), the systems thinking offer an entirely different ways of communications and of working together more productive on understanding and solving complex problem. Regarding the methodology of systems thinking, the system thinking is usually investigated by questionnaires, video analysis, or interviews and concept-mapping technique. The answer could be yes/true, a number, a word or a sentence. As result, through the user interface design the system will communicate the answer to student or will engage student in a pedagogical dialogue. For example, on display is provided a statement  $2 + 2 = \square$  and the learner will write Is this an example of linear or systems thinking? Could these examples be used for problem-solving skills? Each of the systems works step-by-steps. This means that in case of problem solving the issue can be broken in small steps and the student needs to pass one step in order to perform the next step.

For example, if the student passes step I the current value of his/her input for next step will be  $X_i$  and the internal cognitive state will be  $S_i$  which could be transformed into the output value  $Y_{i+1}$  with state  $S_{i+1}$  and so on, according to the corresponding functions. Is this possible using knowledge management systems, for example Moodle or ATutor? If yes, what is Data Visualization Criteria and how the user interfaces need to be designed?

Is this useful to apply systems theory in user interface design of digital textbook? In time when modelling aims to obtain the core structure of competence during learning with/without digital textbooks the design and development of the students' cognitive and behavioural actions are the main issue of systems thinking. The proposed assumption is that correct or incorrect answers need to be proved by feedback from real environments.

## 2.5 Metasystems Thinking

The postmodernism theory emphasises the impact of metacognition on learning. Let us analyse principles of user interface design starting from the postmodernism philosophy. According to the definition, the postmodernism philosophy is associated with the deconstruction and post-structuralism. In our point of view, metacognition may be modelled on the base on MetaSystems Learning Design. Learning is valid when metacognitive strategies are used effectively. Therefore, discrete parameter stochastic processes, changes in probability of occurrence of a response in a small time is more about requirements for effective learning and not about the effective learning processes through digital textbooks.

That is the big difference between our artificially developed skills to project linearly and real world. It's what's really causing *disruptive behaviour of the best students* because they hardly learn how to solve artificial designed tasks in a linear

way, but the world's tasks are more complex and the knowledge is changing exponentially. So a best student that was trained in a linear way doesn't see the exponential digital technology coming out of right field and can put them out of business. Meanwhile, the student who weren't so good in formal schooling may found a company going from zero to billions that are growing in exponential curves.

The modern digital textbook design is assumed to be the coherent product of an author and users of content. The MetaSystems thinking approach involve design and development of the cognitive, affective and psychomotor frameworks. This means that author of the digital textbooks need to think not only about the content, but also about the interfaces, learning styles, how the users will access graphics, assessment tasks etc. Moreover, it is important to estimate the consistencies of screen design, changing colours, font sizes, etc. on different digital devices, as well as to estimate the learning outcomes.

The user interface design needs to be more than an instructional or assessment design.

According to Klir (1990, p. 325), meta X are used as the name of things or systems, which are more than X in sense than it is more organised, have higher logical type of organisation and it is analysed in more general case. Our hypothesis is:

if a digital content contains hypertext or multimodal text, it can be personalised. However, this content should be integrated in a feedback loop with immediate and delayed feedback and will contain a concept mapping tool that will assure a powerful learning environment.

Metasystems approach to learning design relies on post-modernism philosophy of learning, architecture of integrative structure of competence, user interface design principles and learner-centered learning environments. Moreover, conceptual modelling is based on the following principles:

- *principle of self-regulation* (the automatic regulation of learning processes through activation of metacognition using didactical and psychological methods, cybernetics techniques and management systems);
- *principle of personalisation* (the individualization of learning objects through increased formation of the individual as a self and as a member of global learning community);
- *principles of feedback diversity* (electronic educational context needs to be evaluated through immediate and delayed feedback);
- *principle of clarity* (the formation of structural skeleton content with powerful interconnected concepts);
- *principle of dynamism and flexibility* (the learner' active inclusion in elaboration of the content in order to provide the competence development skills)
- *principle of ergonomics* (computer based learning and computer based assessment is guided by ergonomic interfaces and ergonomic places of work).

Analysing the metasystems approach to learning design as educational outcomes of learning, we realised that the evolution of informational technologies conduct to metasystems thinking as an output in learning with electronic textbook. This result is achieved when user interface design criteria provide the evidence of the inter-dependences between information/communication, cognitive and assessment processes.

If so, the students should know not only *cognitive strategies* to complete a variety of academic tasks, but also to effectively apply the *metacognitive strategies*. The metacognitively sophisticated learners invoke both metacognitive strategies (designed to monitor cognitive progress) and cognitive strategies (designed to make cognitive progress). The problem is that some strategies have reliable behavioural indicators, and others do not. However, both readily observed and not readily observed are worthy objects of scientific investigation.

In plus, development of the cognitive and metacognitive strategies requires attentional resources, can be examined, reported and modified by an external 'technological system', and is needed for flexible use. According to Carner (1988, p. 64) the knowing when to use a strategy is as important as knowing how to use it. Therefore, the metacognitively sophisticated learners know whether or not the criterion the criterion task to be completed warrants the costly expenditure of time and effort involved in strategic processing. The values of metacognitive strategies are: creative thinking, critical thinking, design thinking (ecological/sustainable/regenerative design), flexible thinking, futures thinking/anticipatory thinking, flexible thinking, lateral thinking, reflective thinking, and strategic thinking.

## References

- Angerhofer, B. J., & Angelides, M. C. (2000). *System dynamics modelling in supply chain management: research review*. In *Proceedings of Simulation Conference, 2000*, Winter (Vol. 1, pp. 342–351). IEEE.
- B. F. Skinner's Theory. <http://www.theoryfundamentals.com/skinner.htm>
- Benjamin, L. T. (1988). A history of teaching machines. *American Psychologist*, 43(9), 703–712.
- Bosch, O., & Nguyen, N. (2016). Capacity Building and Think2Impact. In *Proceedings of the 59th Annual Meeting of the ISSS-2015 Berlin, Germany* (Vol. 1, No. 1).
- Bronfenbrenner, U. (1994). Ecological Models of Human Development. <http://www.psy.cmu.edu/~siegle/35bronfenbrenner94.pdf>
- Crowder, N. A. (1963). On the differences between linear and intrinsic programing. *The Phi Delta Kappan*, 44(6), 250–254.
- Dick, W., Carey, L., & Carey, J. O. (2001). *The systematic design of instruction*. New York: Longman.
- Eigen, L. D. (1962). A comparison of three modes of presenting a programmed instruction sequence. *The Journal of Educational Research*, 55(9), 453–460.
- Flynn, N. (2016). Performativity and Metaphor in New Materialist Media theory. *networking knowledge. Journal of the MeCCSA Postgraduate Network*, 9(1).
- Frick, T. W. (1991). Restructuring Education through Technology. Phi Delta Kappa Educational Foundation. Bloomington: Indiana. <https://www.indiana.edu/~tedfrick/fastback/fastback326.html/>. Accessed 05.04.16

- Gilman, D. A. (1972). The origins and development of intrinsic and adaptive programming. *Educational Technology Research and Development*, 20(1), 64–76.
- Ha, T. M., Bosch, O. J., & Nguyen, N. C. (2016). Practical Value of the systems-based evolutionary learning laboratory in solving complex community problems in Vietnam. In *Proceedings of the 59th Annual Meeting of the ISSS-2015 Berlin, Germany* (Vol. 1, No. 1).
- Hackman, M. Z., & Walker, K. B. (1990). Instructional communication in the televised classroom: The effects of system design and teacher immediacy on student learning and satisfaction. *Communication Education*, 39(3), 196–206.
- Hairston, M. (1982). The winds of change: Thomas Kuhn and the revolution in the teaching of writing. *College composition and communication*, 33(1): 76–88. <http://www.reiffad.com/genre/Hairston.pdf>
- Handani, M., Charbaghi, A., & Sharifuddin, R. S. (2011). Instructional design approaches, types and trends. A foundation for postmodernism instructional design. *Australian Journal of Basic and Applied Sciences*, 5(8), 1–7.
- Hjorth, P., & Bagheri, A. (2006). Navigating towards sustainable development: A system dynamics approach. *Futures*, 38(1), 74–92.
- INNEPS. (2016). Productive learning. What is it? <http://www.ineps.org/pdf/Productive%20Learning.pdf>
- Joyce, B., Weil, M., & Calhoun, E. (2000). Models of teaching, 6th edn. Allyn & Bacon.
- Karsvall, A. (2002). Personality preferences in graphical interface design. In *Proceedings of the second Nordic conference on Human-computer interaction* (pp. 217–218). ACM.
- Klir, G. (1990). *Architecture of systems problem solving*. New York and Longon: Plenum Press. (In Russian).
- Lazanski, T. J. (2010). Systems thinking: ancient Maya's evolution of consciousness and contemporary systems thinking. *AIP Conference Proceedings*, 1303(1), 289–296.
- Liu, Y., Wu, M., & Sun, Z. (2014). Extending the TAM model to explore the factors that affect intention to use digital textbooks in primary teachers' views. *Intelligent Environments*. Workshop Proceeding of 10th International Conference on Intelligent Environments, 127–136.
- Merrill, D. First Principles of Instruction. <http://mdavidmerrill.com/Papers/firstprinciplesbymerrill.pdf>
- Montuori, A. (2012). *Reproductive learning*. In *Encyclopedia of the Sciences of Learning* (pp. 2838–2840). Springer, US.
- New scientist (2014). Digital textbooks adapt to your level as you learn. <https://www.newscientist.com/article/mg22329832-600-digital-textbooks-adapt-to-your-level-as-you-learn/>
- Richmon, B. (1994) System Dynamics/Systems Thinking: Let's Just Get On With It, International Systems Dynamics Conference, Sterling, Scotland <http://www.iseesystems.com/resources/Articles/SDSTletsjustgetonwithit.pdf>
- Risku, M., Harding, L. (2013). A unified theory. In: M. Risku & L. Harding (Eds.), *Education for tomorrow: A Biocen A Biocentric, student-focused model for reconstructing education* (pp. 113–134). SensePublishers.
- Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional science*, 18(2), 119–144, [http://pdf.truni.sk/e-ucebnice/iktv/data/media/iktvv/Symposium\\_LTML\\_Royce%20Sadler\\_BFormative\\_Assessment\\_and\\_the\\_design\\_of\\_instructional\\_systems.pdf](http://pdf.truni.sk/e-ucebnice/iktv/data/media/iktvv/Symposium_LTML_Royce%20Sadler_BFormative_Assessment_and_the_design_of_instructional_systems.pdf)
- Schlesinger, P., & Waelde, C. (2011). Performers on the edge [video]. *Audiovisual thinking*, 2011 (3).
- Skinner, B. F. (1965). Reflection on a decade of teaching machines. Perspectives and Technology. Teaching machine and programed learning. In Glaser, R (Ed.), *ERIC: National Education Association*, Washington, D.C.
- Smith, K. U., & Smith, M. F. (1966). Cybernetic principles of learning and educational design. Holt, Rinehart and Winston.
- Tchulkina, N. L., & Garbar, O. V. (2016). Secondary Linguocultural Consciousness in the “Instaworld”: Modern Teenager’s World Outlook Forming by Means of the “Picture Creative Thinking” Technology. *Mediterranean Journal of Social Sciences*, 7(1), 449–459.

- Teal, R. (2010). Developing a (non-linear) practice of design thinking. *International Journal of Art & Design Education*, 29(3), 294–302.
- Universal Design of Learning. <http://www.cast.org/our-work/about-udl.html#.V2ZSnqKPVKA>
- Viegas, F., Wattenberg, M. (2011), How To Make Data Look Sexy. [http://articles.cnn.com/2011-04-19/opinion/sexy.data\\_1\\_visualization-21st-century-engagement?\\_s=PM:OPINION](http://articles.cnn.com/2011-04-19/opinion/sexy.data_1_visualization-21st-century-engagement?_s=PM:OPINION)
- Visser, W. (2006). The cognitive artifacts of designing. Lawrence Erlbaum Associates.
- Von Bertalanffy, L. (1972a). The history and status of general systems theory. *Academy of Management Journal*, 15(4), 407–426.
- Von Bertalanffy, L. (1972b). The meaning of general system theory. General system theory: Foundations, development, applications, 30–53.
- Wiener, N. (1948). *Cybernetics: Or control and communication in the animal and the machine*. Paris, Cambridge & Massachusetts: Hermann & Cie, MIT Press.

<http://www.springer.com/978-981-10-2455-9>

User Interface Design of Digital Textbooks

How Screens Affect Learning

Railean, E.

2017, X, 99 p. 12 illus., Hardcover

ISBN: 978-981-10-2455-9