What does the Systems Outcome Mean in ICT?

By Paul Newhouse

Have you ever really understood the system outcome in the Technology and Enterprise learning area, particularly as it applies to computing? If so, you may be able to help me and many other teachers who have had difficulty. Over the past two years I have been involved in the committee that has been reviewing and improving the progress maps for the T&E learning area. Incidentally you can now download the current draft of the progress maps from the Curriculum Council's web-site. Through this involvement and being a writer for the Applied Information Technology course I was confronted with the fact that I really did not have a good understanding of the Systems outcome and therefore I embarked on fairly extensive literature research. I was surprised that there was very little information with a focus on school curriculum, particularly little for IT education. However, I have tried to synthesise what I did find and hope that this may move us forward.

Firstly a brief introduction to the new progress maps and particularly the systems outcome. Although the progress maps are mainly based on the Department's Student Outcome Statements and to a lesser extent the Catholic Education Office's progress maps there are some important improvements. There are now level statements for all seven T&E Curriculum Framework outcomes, including Enterprise, Technology Skills, and Technology in Society. For the other outcomes for which levels already existed levels 4 through 8 have been lowered in difficulty to provide a more even progression from level 3. Each outcome has 'aspects' that were previously called sub-strands. The Systems outcome now has three aspects as shown in the table below.

Systems	
Students design, adapt and use systems that are appropriate to achieving solutions to technology challenges.	
The nature of systems	Understands that systems have elements and processes
The use of systems	Appropriately selects and uses systems
The development of systems	Develops appropriate technology systems

The split between the development of systems and the use of systems has been particularly useful in the AIT course because there is little focus on the development of ICT systems but a major focus on using ICT systems (it is envisaged that the 'Computer Science' course will focus on this aspect of systems). The rationale for this split is that it is appropriate to use a range of very sophisticated systems and understand their nature without necessarily developing them. That is that it should be possible to make use of the outcome without having to insist that students develop a system. This argument would not hold for the Information outcome as it is almost impossible to use information without actually constructing it at the same time because the way you use the information automatically adds your own meaning and thereby constructs new information.

The progress map goes on to elaborate on the outcome by providing a statement for each of the levels and for each of the aspects. For example the statements for level 4 are given below.

S 4 Explains how the elements of a system interact and uses this information to control and adapt existing systems and design and create solutions to new technology challenges.

S 4.1 Understands that the elements in simple linear systems interact in a sequence to use inputs to meet different technology needs associated with underpinning values.

S 4.2 Controls and maintains simple linear systems through a variety of means using supplied techniques and applies knowledge of the elements of these systems to the selection, control and testing of the systems to meet technology needs.

S 4.3 Designs and constructs efficiently new simple linear systems, choosing resources appropriate for the particular system environment and based on developed design criteria.

Then there is a full page elaboration for each level statement as in the example below.

Elaboration - Level 8

Students understand how the design, operation and management of complex systems influence the impact of the systems on communities and environments. Their in-depth exploration of the form, structure, organisation, operation and management can be applied to complex tasks related to the construction and operation of systems. Through study of the historical development of systems (mechanical, electronic, computing, organisational, management, business, production, transport or energy) in different cultures and environments, they increase their understanding of the benefits and costs of particular systems and the way they contribute to the development of societies. This understanding enables them to make decisions regarding the design, operation and management of systems in a range of cultural and environmental circumstances.

The nature of systems

Students investigate the development and application of new and emerging systems. They research the application of systems to achieve social goals and analyse the human, environmental, social and economic consequences of particular systems. Students explore the way in which the computer has transformed society. Students understand that global economic growth depends on energy use. They determine the benefits and costs of energy sources such as fossil fuels, and renewable and human energy sources. They apply these understandings to a range of technology challenges. They understand the complex issues associated with individuals and communities adopting innovations that reduce the impact systems have on the environment.

The use of systems

Students operate and manage complex systems to understand the structure of such systems and their logic, sequences and control, and their relationships to the impact on communities and environments. They can describe these aspects using mathematical, scientific and organisational principles. They are thus able to apply understandings in managing the system, optimising its performance and controlling its impact on communities and the environment.

The development of systems

When devising complex systems, students consider the needs of clients and users. They use appropriate modelling techniques and systems analysis to analyse and justify the development and application of systems in terms of their technical performance and human, environmental, social and economic consequences. They develop and test their systems. Their designs and production proposals contain graphics, technical language, descriptions of the merits of alternatives, and evaluations of the projected impact on communities and environments. When producing systems, students implement processes that ensure the specified standards for quality and safety are achieved, and that optimum use is made of time, resources and equipment. They also assess the social, cultural and environmental impact, to determine short- and long-term consequences of their systems.

And then a series of pointers are given for each level as in the example below. But as you will notice there are almost no pointers related to ICT systems.

Pointers - S 8.3

The student effectively and efficiently devises, justifies, constructs, and tests complex systems considering the needs of clients and users, and their technical performance and human, environmental, social and economic short- and long-term consequences.

This will be evident when students, for example:

- *prepare a supermarket promotion for bush foods and recipes for bush food*
- *evaluate the effectiveness of breeding programs, using traditional criteria for selection versus modern techniques, such as Expected Breeding Values*
- *program a personal computer with a password system to ensure confidentiality of nominated files and graded access to others*
- *assemble an electronic switching device to open and close a gate, using soldering techniques with the precision needed to achieve specified reliability and performance standards*
- *develop a system for colouring fabric that incorporates a range of dyes and techniques, and compare with commercial production*
- *assemble and install an automatic home garden irrigation system that operates according to time, soil moisture and light intensity.*

The question now is how can all this be applied to ICT systems. The discussion below aims to start this development of a common understanding.

What is a System?

There are “three different interpretations of the system” (Ropohl 1999): structural, functional, and hierarchical. According to the structural interpretation a system includes “a set of elements and a set of relations between these elements”. The functional interpretation views a system as an entity which “transforms inputs into outputs, depending on specific internal states; the kind of transformation is called a function”. The hierarchical interpretation views systems as comprising subsystems and being subsystems of more extensive supersystems. There is an assumption that every system has an “outside” and an “inside”, an “external behavior” and an “internal construction”.
Four basic laws of systems (Ropohl 1999):

1. The system is more than the set of its elements (because, above all, the set of relations determines the very character of the system).
2. The structure of the system determines its function.
3. The function of the system may be produced by different structures (principle of equifunctionality).
4. The system cannot be described completely on just one level of hierarchy (principle of excluded reductionism).

“These laws, of course, will have different consequences in specific scientific applications.”

Mental models are useful for analysing “(a) the function of a system, (b) the structure of the system, and (c) the behaviour of the system” “Schematic Diagrams use abstract symbols to represent the component parts of a technical system and connect those abstract symbols with lines to indicate their relationships.” “Functional flow diagrams represent the fundamental concepts or essential component parts of a system and organise meaningful relationships between those concepts and component parts.” (Satchwell 1997)

“A system may be most simply defined as a set of interrelated elements. In other words, a system is made of at least two or more parts that are physically or logically interrelated to each other. It makes no difference whether the system is a concrete physical thing, such as an air conditioning system, a methodology for performing some task, or something abstract, such as in a philosophical system or a social system. Likewise, the interrelationships can be either tangible or intangible. The essential thing is that the system is composed of interrelated parts but can be perceived as a

whole. Furthermore, from a systems perspective, this whole is more than the sum total of the parts of the system." (http://www.smeal.psu.edu/misweb/systems/sycodef.html)
"A system, therefore, consists of two basic components: elements and interrelationships. Think, for example, of an automobile. There is an engine, wheels, seats and a steering wheel, as well as many other components. Each entity that composes the automobile is a distinct element, and can exist independently although it may not be able to usefully function without its related components. Some of these components are themselves grouped into sub-systems. A sub-system is any identifiable component of a larger system that, itself, is made up of interrelated elements. You may have heard people refer to the vehicle's "electrical" or "exhaust" system. However, until all of these components are placed together in the total context of an automobile, they do not work together. When all of the elements are properly connected to one another, they are able to work together as a whole constituting the entire "automotive system." In systems terminology, the connection between the elements is called the interface." (http://www.smeal.psu.edu/misweb/systems/sycodef.html)

What is an ICT System?

Given the broad definition of systems it is clear that an ICT system could be conceived equally broadly. Usually it will involve hardware, software and personnel but what is considered as a system may depend on the purpose of defining the system and the level to which it needs to be represented/defined. For example, while a personal computer could be described as a complex system in its entirety and applied to complex tasks when applied to downloading web-pages it could be described as a simple linear system. Similarly its hardware could be represented as a complex system or as a simple linear, input-processing-output system. Generally it is probably important not to just focus on personal computer hardware but to focus on the application of ICTs and the particular systems thus generated. Also it will be necessary to consider the level of detail students need to understand a particular system.

All ICT systems are dynamic as they produce outputs in response to inputs received from their environment. What is considered as a system may depend on the purpose of defining the system and the level to which it needs to be represented/defined. For example, a personal computer could be described as a complex system in its entirety and applied to complex tasks but when applied to downloading web-pages it could be described as a simple linear system. Further, PC hardware could be represented as a complex system or as a simple linear (input-processing-output) system

An ICT system is not just a computer rather a system that involves the use of a computer(s) to meet a need. Therefore an ICT system could be a just a self-contained computer system such as a PDA or a networked system such as a LAN. It is most likely that an ICT system will be a specific purpose system using particular software, hardware and personnel elements such as,

- a web-based email system,
- a publishing system (e.g. input of text and graphics into MS Publisher and output to PDF or printer), or
- a complex computer-based system for the management and operation of the milking of cows.

Therefore it is important not to just focus on personal computer hardware but to focus on the application of ICTs and the particular systems thus generated. Always consider the level of detail students need to understand a particular system.

Linear, Non-Linear and Complex ICT Systems

A critical concept embedded in the systems outcome is the level of complexity by which the system is described. At the simplest level a linear systems are made up of elements and processes that are sequential and pre-determined, that is have a direct cause and effect. Examples of such ICT systems may be: a web-based email system, a locally connected printer system, a system for downloading digital photos from a camera, etc.

Non-linear systems are made up of elements and processes that are not sequential or pre-determined and provide multiple pathways. They may include linear subsystems. Simple non-linear systems tend to be hierarchical. Examples of such ICT systems may be: a publishing system (e.g. input of text and graphics into MS Publisher and output to PDF or printer), a PDA, etc.

Complex systems display adaptive, self-organising behaviour and are usually characterised by a large throughput (Center for Complex Systems Research, University of Illinois). They require non-linear processes and control mechanisms. Examples of such ICT systems may be: a computer-based system for the management and operation of the milking of cows, a local or wide area network, etc.

What do the students need to understand and use?

The level statements for the outcome indicate what students need to understand and how this may be demonstrated. This does not mean that students will not use more sophisticated systems than they are judged to have an understanding for. They will use systems they don't understand to demonstrate other outcomes, their use will be directed by the teacher's understanding. This is quite acceptable from a practical and educational perspective. Practically we all use systems we do not understand. Educationally, we all learn by working with scaffolding (Zone of Proximal Learning).

Functions of ICT System Components

These are fundamentally described in terms of input, output, processing, memory, and communication. There are hardware and software components of ICT Systems that perform these functions. To successfully perform these functions the hardware, software and personnel elements must work together. Particular components of the hardware and software must be configured to perform the functions and how each is configured will determine the quality of the performance of the system.

Progression of Understanding

It is critical that students are able to demonstrate the progression in their understanding in relation to the systems outcome. This will be represented by key concepts such as the complexity of representation of the system, explanations and applications of understandings of the components of systems, their functions and interrelationships, the standards of performance of various forms of systems, and so on. Some definitions of key concepts are provided in the final section below, perhaps you can add others. For the AIT course we developed the follow elaborations of the outcome relating to only the first two aspects. Then we described each of the elaborations for levels 4 to 8 (if you are interested in the detail download it from the Curriculum Council's site or contact me).

In achieving this outcome, students:

- understand a variety of forms of ICT systems designed to meet client and user requirements and their impact on individuals, communities and the environment;
- understand the management, purpose, roles and interaction of the hardware, software and personnel elements of various forms of ICT systems to meet requirements and control impacts;
- understand the functions, types and interrelationship of the hardware and software components of ICT systems and their configuration to meet requirements; and
- understand the key standards and procedures related to various forms of ICT systems and their relationship with client and user requirements.

Definitions of Terms

Form of ICT system	Form = shape or appearance; configuration. (Collins Dictionary) For an ICT system this involves the overall configuration of the hardware, software and personnel. For example, the hardware may be a PDA using a networked PC for wireless synchronisation, the software will include operating and applications software, and the personnel may involve the user with the support of a network of consultants.
Element of ICT system	Element = a component part; constituent. (Collins Dictionary) For an ICT system an element is either hardware, software or personnel. Note: sometimes the term component is used but we are reserving it to describe sub-elements. Also sometimes data is used as an element but here we are defining software as instructions & data.
Component of ICT system	Component = a part helping to make a whole. (Collins Dictionary) The hardware and software elements of ICT systems are made up of components that perform the functions of processing, input, output, memory and/or communications. Both hardware and software components are required to perform such functions.
Standard of ICT system	Standard = measure or quality to which others must conform; criterion; serving as established rule. (Collins Dictionary) There are sets of standards that have been created to describe the operation of the elements and components of ICT systems. Some standards are set by governments or associated statutory bodies, some by international organisations, some by manufacturers, some by user organizations, and some by local authorities or organizations. For example TCP/IP provides a standard protocol for the WWW.
Processes of ICT system	Processes = a series of actions or measures; a method of operation. (Collins Dictionary) The processes used with ICT systems to use them to meet requirements.
Configuration of Components	Configuration = outward shape or form; aspect. (Collins Dictionary) Most software and hardware components have features that may be adjusted to vary the operation of the component.

In Conclusion

While I hope that this discussion has moved forward a little our shared understanding of the application of the systems outcome to ICT education I know there is a long way to go and implementing this understanding in practical learning activities will not be easy. I would encourage you to add to this discussion by putting forward your own thoughts in later editions of Login.

References

Ropohl, G. (1999). "Philosophy of socio-technical systems." Techne: Journal of the Society for Philosophy and Technology. **4**(3): 59-66.

Satchwell, R. E. (1997). "Using functional flow diagrams to enhance technical systems understanding." Journal of Industrial Teacher Education **34**(2): 1-14.