Concept Representation Resources 3

Learning Outcomes:

- Describe a concept representation as a special form of digital resources for learning;
- Appreciate complexity and importance of concept knowledge in overall disciplinary knowledge;
- Understand the challenges of concept teaching and propose and activity as a solution for effective learning;
- Analyse own concept knowledge and resources to identify a concept's properties, parameters, relationships and related sub-concepts;
- Design a concept representation based on own knowledge of a specific concept; and
- Apply design for presentation recommendations to the design of a concept representation.

3.1 What Is a Concept Representation?

A concept representation resource is a particular kind of digital resource for learning designed to support the learning of disciplinary concepts. Such representation allows a learner to manipulate properties, parameters and relationships, and explore relevant information related to a concept. Properties, parameters and relationships are displayed in depictive and descriptive ways with variety of modes or representations such as textual, numerical, pictorial, graphical, animated, auditory,

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video, special effect etc. Properties are manipulated with interactive elements such as sliders, text entrees, hot-spots and buttons.

A simple example of a concept representation resource is presented in Fig. 3.1. This concept resource represents a right-angled triangle and its associated properties, parameters and relationships (a concept of a right triangle). It allows a learner to manipulate parameters including base and height of the triangle by dragging corresponding sliders. Manipulating either of the two parameters of the triangle (base or height) by dragging the sliders will result in an immediate update of the display (changes in properties), that is, the triangle will be redrawn in a corresponding size, and the numerical information regarding dependent parameters (such as the value of the hypotenuse) will be updated. These changes are driven by certain relations, which learners will explore during their learning activity.

This resource can be reused for different activities and with different groups of students. For example, lower grade students could use it to explore the properties of a right-angled triangle, while more senior students might explore concepts such as Pythagorean theorems and basic trigonometric functions (sine and cosine) in the contexts of their activities.

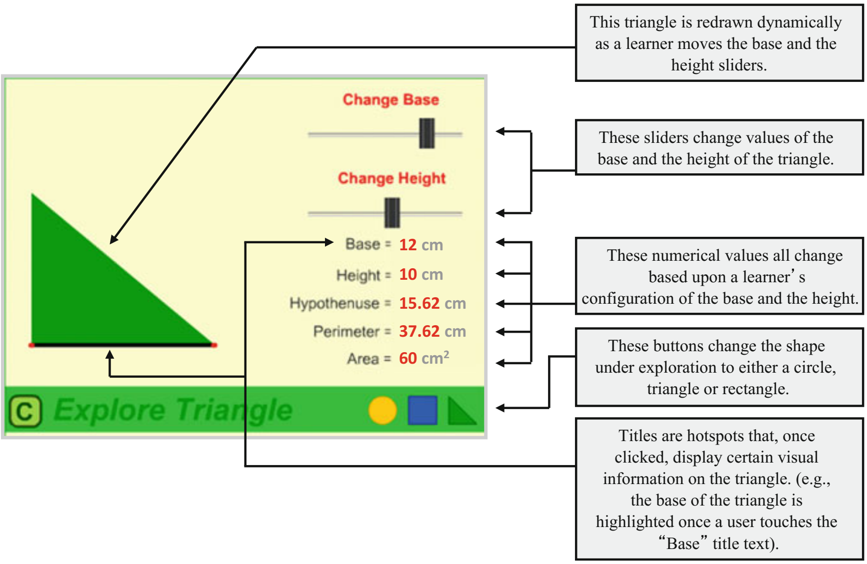

Fig. 3.1 "Explore Triangle" concept representation resource (from Churchill and Hedberg 2008b)

3.2 What Is a Concept?

Important
A concept is a complex and genuine act of thought, and a psychological or intellectual tool that forms a basis for our cognitive activities. As a disciple-specific tool, framework or a schema it underlines theoretical thinking.

The intention of this chapter is not to be drawn too deeply into a philosophical discussion of what a concept might be. However, it is worth noting some issues. This is a very complex discussion that has not reached a conclusion since the time of Plato and Aristotle, although some of the best-known names in psychology, philosophy and education, such as Kant (1922), Piaget (1972a, b), Vygotsky (1962), Dewey (1910), Bruner (1960) and Gagne (1971), explored it. Existence of concepts in someone's head cannot be really proven empirically, although neuro-scientists are attempting to do so based on various emerging possibilities brought about by new biometric technologies (e.g., Functional Neuroimaging). The construct of a concept has been largely explored by psychologists and philosophers with interest in the forms of knowledge and how these develop in individuals' cognition, as well as those who subscribe to theories of cognitive, information sciences or neurosciences (e.g., Bruner et al. 1967; Dewey 1902, 1997; Gagne and Driscoll 1988; Hartnack 1968; Hjørland 2009; Lawrence and Margolis 1999; Li et al. 2015; Piaget 1972a, b, 1990; Stock 2010; Traill 2008; Turner 1975). A concept is broadly understood as a form of knowledge that enables an individual to comprehend new information and learn, communicate and understand language, and engage in specific disciplinary thinking, decision making, problem solving, generalizing, reflecting, making inferences and forming and reconstructing personal theories. There are various interpretations in the literature, such as, a concept is a fundamental unit of cognition, a node-in network in a knowledge schema, patterns of synaptic connections, a system for classifying objects into categories, or a psychological tool for thinking. For example, Vygotsky and his followers define a concept as a complex and genuine act of thought, and a psychological or intellectual tool that forms a basis for our cognitive activities (e.g., Vygotsky 1978; Ivarsson et al. 2002; Kozulin 1990; Sierpinska 1993). For Engeström (1987) "individual consciousness is formed under the influence of knowledge accumulated by society and objectified in the world of things created by humanity" (p. 36). A concept is, therefore, understood as a socio-cultural phenomenon developed by humans in their attempt to interpret the nature and ways of conquering it. Pursuing a different line of thought, Merrill et al. (1992) describe a concept as "a set of specific objects, symbols, or events which are grouped together on the basis of shared characteristics and which can be references by a particular name or a symbol". Such a view is in contrast with Vygotsky's perspective of concepts as psychological tools, and more in line with what Jonassen (2006) labels as *Aristotelian position* that assumes concepts are representations of classes of objects, symbols, or events grouped together based on common properties or attributes. However, in all these, a concept is a form of knowledge that is not simply declarative.

In this book, we like to think of a concept as a disciple-specific act of thought, framework or a schema for theoretical thinking. It is essentially socio-cultural, that is, a concept is a representation of knowledge accumulated by humanity, and not just as something that might exist independently in one's own mind. Applications, generalizations, reflections and abstractions based on a concept lead to the formation of concept knowledge, which then serves as internal disciplinary tools for theoretical thinking, or a psychological tool. Disciplined specific concept knowledge are the foundation of one's theoretical thinking and his/her ability to intellectually operate within that discipline (e.g., solve problems or conduct a research in the way that scientists do).

Concept knowledge contains both, declarative and procedural knowledge reconstructed from experiences and integrated in an internal tool for thinking. This knowledge can only be exhibited through our activities such as problem solving, designing, innovating, decision and inference making, but not simply by asking a learner to use words and describe a concept learnt.[1] We know that performing these activities requires knowledge that simply is not only declarative, but also procedural, and involves applications of some higher forms of cognitive activity and strategies rather than simply recalling facts and definitions (e.g., mental modelling, cognitive simulation, cognitive visualization and imagination).

Furthermore, we need distinguish between everyday concrete concept knowledge, which is developed spontaneously through experiences, life, growth, games and social interaction with parents, relatives and friends, and those more abstract concept knowledge formally developed over time through formal education and learning (formal or scientific concepts). For Kant, some concepts originate in the mind itself through various processes such as comparing mental images, abstraction and reflection based on these (he calls these priori concepts). Inevitably, there is a relationship between these informal and formal concepts, and knowledge and learning of them, affecting knowledge and learning and re-learning for the others, once their developmental trajectories somehow intersect.[2,3] However, how formal concept knowledge is developed is based on organized, systematic, intentional, planned, and educator-managed learning designs that represents the interpretation of curriculum requirements into a set of learning and teaching actions.

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[1]To evaluate concept knowledge, the literature suggests techniques such as think aloud problem solving and concept mapping (see Jonassen 2006).

[2]Learning of formal concept knowledge does not start in a vacuum. It builds upon student's concept developmental levels and prior knowledge, which might include, formal conceptions, spontaneous conceptions and misconceptions.

[3]Vygotsky in "Language and Thought" wrote about how every day and scientific concept knowledge develop, and how their developmental trajectories intersect.

Important
A concept representation resource is a particular kind of a digital learning resource designed to support the teaching and learning of disciplinary concepts.

From a different perspective, concepts develop over prolonged periods of time, passing through certain stages. Most studies appear to explore student misconceptions of specific concepts rather than the generic process of concept development. To gain a better understanding of that process, we can draw on the theoretical perspective of Vygotsky (1962) and those who subscribe to it (e.g., Berger 2004a, b; Blunden 2011; Scott 1997; Sierpinska 1993; Wellings 2003). For Berger (2004a), "Vygotsky's theory around the genesis of concepts is a theory around the genesis of intellectual operations such as generalization of objects and situations, identification of features of objects, their comparison and discrimination (that is, their abstraction), and the synthesis of thoughts" (p. 3). Therefore, a concept is an act of thought. According to the Vygotskian perspective, concepts develop through pre-conceptual stages, including syncretic heaps (characterized by subjective grouping of unrelated objects by chance), complexes (grouping of objects in the mind, not only by subjective impression, but by bonds that actually exist, in forming associations, collections, chains, and pseudo-concepts) and, finally, socially and culturally accepted scientific concepts (Berger 2004a, b; Blunden 2011). For Vygotsky (1962), "a concept is not an isolated, ossified, and changeless formation, but an active part of the intellectual process, constantly engaged in service of communication, understanding and problem solving", and the process of concept appropriation "is not a quantitative overgrowth of the lower associative activity, but a qualitatively" new activity mediated by signs (e.g., language, symbols, and internal images) (p. 109). Both social interaction and interaction with spontaneous concepts are seen as critical in scientific concept formation.

Concepts in a school curriculum (or any other education or training curriculum), are there because they are determined by experts in the fields over time.[4] We include concepts such as force, ratio, energy, landforms, trade, freedom, velocity, vector, polygon, evolution, cell, inflation, poverty, acid rain, adjective, idiom, revolution, human rights, magnetic field etc. in a curriculum given our up-to-date progressively developed understanding of disciplines' concept tools. These concepts all have socio-cultural histories, some emerging years ago and undergoing public revisions since then. They are articulated through human attempts to interpret and deal with nature and their own self, and emerge as a tool in this process (e.g., Activity Theory perspective). For example, a force, philosophers in ancient time, such as Aristotle and Archimedes, used this concept in the study of stationary and moving objects and

[4]There are other factors determining curriculum content such as expectations of society, industry requirements, education policy-making, pedagogical content knowledge, philosophy of education, etc. [see Tyler (1949)].

simple machines. At that time, they were not able to completely understand the force of friction, and consequently held the belief that a constant force is required to maintain constant motion. These misunderstandings were mostly corrected by others including Galileo, and later by Sir Isaac Newton who formulated *Laws of Motion*. By the 20th century, Albert Einstein had developed the *Theory of Relativity* providing and insight into forces on objects with increasing momenta nearing the speed of light, and the forces produced by gravitation and inertia. More recently, quantum mechanics and particle physics have resulted in a Standard Model to describe the forces between particles smaller than atoms. So, it can be understood, a concept of force has been under continuous development since ancient times.

Activity 3.1

Think of any concept. For example, what is your concept of 'Heat?' Can you write a sentence to explain what 'Heat' is? Read this sentence and think whether you really understand what 'Heat' is? How easy it would be for others to understand the content of your sentence? Would words in your sentence be sufficient for them to understand the concept?

Most likely, your definition of the everyday concept of 'Heat' associates you with certain other concepts, such as warmth, sun, summer, candle, matches, blanket, bath, or weather. However, let's now think about the scientific concept of 'Heat' and what it might include. This might significantly differ, and yet, in some ways overlap with your everyday conception. Would everyday conception lead you to form a misconception of the scientific concept? Think about that.

But let's do something else. Think of the scientific concept of 'Heat'; consult the literature and people if needed, list down all associated sub-concepts, properties, parameters and relationships, and use a mind-mapping tool of your choice (e.g., Mind42 or Mind Meister) to create a mind map containing and linking all these. Discuss your map with your colleagues, class peers, a teacher, etc. How does mind-mapping help you to articulate your understanding, expose your misconception and think about the concept?

3.3 Concept Learning

The literature underlines the importance of concept knowledge and refers to evidence that incomplete concept knowledge and misconceptions seriously impede learning (see Mayer 2002; Singer et al. 2012; Smith et al. 1993; Vosniadou 1994). However, concept learning has been challenging for teachers and students, as it requires deep cognitive engagement, and individual preconceptions and misconceptions tend to present obstacles. It is widely held that concepts develop from fragmented, piecemeal, and highly contextualized naïve theories, misconceptions, and incorrect beliefs at the level of a single idea, flawed mental models representing an interrelated set of concepts, and/or the incorrect assignment of core concepts to laterally or ontologically inappropriate categories (e.g., Chi 2008; diSessa 2008).

Important
A purpose of concept learning should be the gradual approximation of sociocultural and individual concept knowledge and development of intellectual disposition to engage and apply that knowledge in theoretical thinking.

Merrill et al. (1992) suggest students might develop misconceptions, and that instruction should be designed such that this is prevented, and that a concept learnt by learners is the same to that held by a teacher (or as intended by a designer of an instructional product). Merrill et al. (1992), present an instructional design model that arguably can be applied to optimize concept learning. A concept representation is promoted as an object that supports instruction, usually to depict and describe examples, illustrating attributes of a concept to be learnt. For Merrill et al. (1992), learners learn a concept through pattern recognition; that is, by recognizing (a) how a concept structurally relates to other concepts, and (b) how attributes of a concept relate to each other and link to prior knowledge. Two cognitive processes involved in pattern recognition are generalization and discrimination. Merrill and his colleagues' ideas influenced other instructional design models such as Cisco's Reusable Learning Object strategy (Cisco Systems 2001). For Cisco Systems, a concept is "a group of objects, symbols, ideas, or events that are defined by a single word or term, share common features, and vary on irrelevant features" (p. 16). Numerous other instructional design researchers and practitioners subscribed to this classical view that concept learning involves internalizing external concepts (e.g., Canelos et al. 1982; Carrier et al. 1985; Gagné 1966, 1968; Hicken et al. 1992; Jonassen 1978, 1986; Merrill 1983, 1987; Merrill et al. 1977, 1979, 1992; Montague 1983; Newby et al. 1995; Tennyson 1978; Tennyson and Buttrey 1980; Tessmer and Driscoll 1986). However, Jonassen in his later writings (see Jonassen 2006), rightly criticizes and challenges this thinking, and argues that concepts can only be learnt in context of their intellectual uses that lead to conceptual changes and the development of personal theories. Therefore, instruction should lead students to engage in the intellectual uses of concepts though experiences designed and facilitated by teachers (learning designs).

Provision of certain models is believed to have a positive effect on concept learning (see Ivarsson et al. 2002). Dawson (2004) in his book "Mind and machines" writes that a model is an artefact that can be mapped on to a phenomenon that is difficult to understand. Furthermore, Dawson writes, by examining the model a learner can increase understanding of a phenomenon (concept) modeled, and although a model can imitate a phenomenon, it most often does not reassemble it, that is, it is a representation of a phenomenon rather than a copy or an identical replica. However, Dawson adds, a property common to all models, appears to be the notion of 'predictive utility'. A model is used to generate predictions that can be used to test a theory and, thus, it might provide an easier and faster route to learning. Similarly, others have suggested models as effective tools for concept learning, and their educational use has been described as model-centred learning and instruction (see Dawson 2004; Gibbons 2008; Lesh and Doerr 2003; Mayer 1989; Norman 1983; Seel 2003). For example, Lesh and Doerr (2003) define a model as "a concept system consisting of elements, relations, operations, and rules governing interactions" (p. 10). Such models can be used for constructing, communicating, describing, or experimenting with a system (see Johnson and Lesh 2003).

Important
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Engaging students to use technology to develop concept knowledge has been explored in the context of cognitive tools (Lajoie and Derry 2000), mindtools (Chu et al. 2010; Jonassen and Reeves 1996; Jonassen 1996; Jonassen and Carr 2000), and technologies of the mind (Pae 1985; Salomon et al. 1991). Examples of cognitive tools include computer-based tools such as system modeling applications, e.g., Stela and Interactive Physics; knowledge organizing tools, e.g., database software, knowledge construction tools e.g., Knowledge Forum; and idea processing tools, e.g., Mind Manager and Axon. According to Jonassen (2006) and Chai and Quek (2003), cognitive tools are used to engage students in exploring and analysing how variables interact in a manner that can be defined mathematically or in terms of other properties, identifying relationships between categories of relevant information, and linking relationships within and between concepts. For Jonassen (2006), cognitive tools have been "adapted or developed to function as intellectual partners with the learner in order to engage and facilitate critical thinking and higher order learning" (p. 9). After being presented with a problem or inquiry that includes the particular phenomenon to be examined, students build a representation to help them to understand it and/or develop solutions. Using cognitive tools, learners create artefacts, representations, or external models representing their thinking while engaged in the knowledge-construction process. These tools support knowledge construction by enabling learners to learn *with* rather than *from* technology, generating questions and predicting outcomes, creating meaningful data structures and generating hypotheses, and enhancing such skills as collaboration, communication, metacognition, and resource organization (e.g., Chai and Quek 2003; Jonassen 2006; Jonassen and Reeves 1996). Interpersonal engagement is critical in this type of learning.

However, in the context of this book, we are exploring the design and uses of representations that are already designed, and made available for learners as tools in their learning activity. De Jong and Joolingen (1998) in their paper "Scientific discovery learning with computer simulations of concept domains" specify a number of possibilities including hypertext environments, concept mapping environments, interactive representations (simulations), and modelling environments. Today's technology adds an important advantage of enabling the design of concept representation resources and models in interactive multimedia format (see Churchill 2013; De Jong et al. 1998; Fraser 1999; Johnson and Lesh 2003; Norman 1983; van Someren et al. 1998). It is suggested that these concept representations support learning through the activation of certain cognitive processes such as reflection, mind modelling, abstraction, reconceptization and linking between internal representations (e.g., Churchill 2008; Seel 2003; Mayer 2003). The gradual *interiorization*, or *appropriation* (the term used by such scholars as Vygotsky (1978), Davydov (1999), Sierpinska (1993) and Kozulin (1990), of the features of concept representations through their intellectual uses in such operations as generalization, identification, comparison, discrimination, and synthesis of thoughts within a learning activity will lead to deeper disciplinary concept knowledge. If a psychological tool for theoretical thinking involving a concept is absent, a representation of that concept (concept representation resource) might be supplied externally. This might be one way how technology can provide an intellectual partnership in order to support disciplinary thinking and activities.

It is important to note that even the most appealing concept representation resource might not be effective unless it is appropriately integrated in educational activities. Pedagogical effective use of a concept representation resource must be driven by an activity (Churchill and Hedberg 2008a). For Foo et al. (2005), an activity design (learning design) should be a central concern for a teacher engaged in instructional planning. Mayer et al. (2003) suggest that an activity should present learners with a conceptually demanding question that requires deep intellectual engagement (theoretical thinking). In this context, a concept representation resource design must be informed by possible learning uses, and allow learning to happen in the process of concept changes and development of personal theories based on that experience. Concept learning, in most cases, is not possible simply through declarative knowledge presentations and traditional instruction. Such a strategy is likely to result in misconceptions, incomplete conception, and temporary remembering of certain definitions or other information, or no learning at all. Effective concept learning requires activities that include generalization, abstraction, and the building of personal theories, reconceptization and application of concept knowledge. Digital resources for learning are only one component in a learning design. It is an activity that creates context for these resources to be deployed and used. In many cases, digital resources for learning are effective, but there are numerous situations where other forms of resources alone or together with digital ones, will prove to be more effective for concept learning. Digital resources for learning might also play other roles in learning activities such as providing support and remediation.

Finally, in conclusion of this difficult discussion, concept learning is not simply mapping or copying of external content, models, and representations of someone's knowledge into learners' mind. A concept needs to be deconstructed (e.g., through analysis of its properties, relationships and parameters), and reconstructed in the mind (e.g., through generalization and abstraction) in order for concept learning to happen.

A concept representation is a representation of a concept, not a copy or a replica. A purpose of concept learning should be the gradual approximation of sociocultural and individual concept knowledge and development of intellectual disposition to engage and apply that knowledge in theoretical thinking. Therefore, when we discuss an idea of a concept in the context of this book, we consider it to be a specific form of sociocultural knowledge, not as a something that strictly exists in and is copied across minds. Concept learning should result in conceptual knowledge; a tool that supports theoretical thinking, or a psychological tool. However, concept learning is often a prolonged process of gradual approximation of learners' thinking and concept knowledge on one side, and concepts specified by the curriculum and determined in the context of their socio-cultural development within a discipline on the other. This is to say that concept knowledge has its own personal development trajectory that intersects with sociocultural trajectory in the context of formal education.

Most of the design and research work of the author of this book focuses on concept representation resources. Previously, the author referred to such digital learning resources as 'concept models', however, this term has been abounded in this book. The author holds that this kind of resources are critical for learning, and that education media designers should dedicate much more attention to them, especially in the context of emerging mobile representational technologies that allow access to resources at anytime and anywhere. A special form of intellectual partnership with technology might be achieved when learners' concept knowledge is supported by externally supplied concept representations. This book gives strong attention to these kinds of resources, elevating their importance for learning at all levels. Ultimately, education should, instead of filing in learners with information, empower these learners to develop their own concept tools for their intellectual activities within disciplines and beyond.

Activity 3.2

How are concepts learnt by learners? How do you learn a concept? Let's recall your experience in Activity 3.1. How did mind-mapping help you to learn the concept of 'Heat?' Think about this, and discuss your ideas with your peers. Try to develop your claim about how concepts are learnt based on your own experience. However, how do you know that the concept you learnt is not actually a misconception? Reflective learning practice is critical for concept learning. What you are asked in this case, is to reflect back on your own conceptual knowledge and examine it with aid of your mind-map. However, most effectively, reflections occur in the context of some intellectual use of a concept, that is, some problem to solve or other task requiring that conceptual knowledge to be examined, refined, tested etc. *So, describe a task, inquiry or a problem solving where learners might use their concept of 'Heat' in a reflective way.*

3.4 Designing and Developing a Concept Representation Resource

A concept representation is developed through the following stages:

- Identify/Determine a concept for design.
- Specify concept's particulars.
- Design a storyboard specifying how a concept content will be represented:
  - Determine context for the concept representation;
  - Determine functional areas of the screen;
  - Determine modes of representation; and
  - Determine interactive elements.
- Develop a prototype of the concept representation resource and evaluate it.
- Develop the final concept representation resource.

We will illustrate these phases through an example of a concept representation resource designed to facilitate the learning of the concept of Velocity.

3.4.1 Identify/Determine a Concept for the Design

A process of design of a concept model begins with the curriculum analysis and identification of a concept(s) to be represented through a concept representation resource(s). It is assumed that the best outcome can be achieved by systematic analysis of a curriculum, identification of concepts and the relationship that exists between these, rather than by identifying based on some criteria of a single concept for development. Relationships will define groups and sub-groups that include sets of concepts. For example, a group/topic of mechanics might contain various concepts such as: density, gravity, space, time, displacement, motion, position, direction, velocity, acceleration, mass, momentum, force, energy, torque, conservation law, and power. Some of these concepts can be grouped together (in a single or multiple groups) when determining final concept representation resources to be developed, e.g., velocity, time, displacement and acceleration, or acceleration, mass and force.

We might take the first example of a group of concepts (velocity, time, displacements and acceleration) and include it in several concept representation resources, with the main focus changing from the concept of velocity to acceleration and displacement. So, one concept representation can be designed with the main focus on velocity, and another separate concept representation can be developed with the main focus on acceleration, for example.

In practice, many educators decide on a concept based on their experience and opinion, rather than through any systematic analysis of curriculum content. Some educators are guided by thinking about importance of certain concepts over other concepts, or selecting those concepts that are difficult for students to understand, or due to personal theory that a particular concept can be effectively taught through the use of representational technologies. That is the reason why we might find that there are numerous concept representations based on the same set of specific concepts, while there are other concepts that have not been included at all. What determines an educators' decision are his or her private theories about issues such as what is learning, how his or her students learn, technology, roles of a teacher, and assessment (see Churchill 2005).

3.4.2 Specify Concept's Particulars

The next step in the process is to determine and specify particulars including related concepts, properties, parameters, relationships and information. The following particulars presented in the completed planning form should be determined and specified (see Table 3.1).

3.4.3 Design a Storyboard Specifying How a Concept's Content Will Be Represented

A storyboard, in the formal sense, is a blueprint for the development of the final product, a quality assurance document, a design specifications document, project team management tool and a tool for managing client-developer relationship and issues. As a formal document, a storyboard specifies all particulars in sufficient details to enable a project manager to coordinate the process, and the development team to develop the media required, and integrate these in a final product or a prototype. Depending on a kind of digital learning resource, sometimes, a preliminary set of flowcharts might be needed in addition to storyboards, but in the case of a concept representation resource, this might not be always needed.

However, this book is not so much concerned about formal multimedia development project management and processes, although all of these ideas from this book do apply in that context as well. The purpose of the book is to provide a useful guide and empower educators to understand, select and engage in the design of resources for their own practice. In the informal sense, a storyboard can be a tool to assist a designer (e.g., an educator) to articulate ideas and arrive at a sketch of an intended final product before commencing any development, or before passing that storyboard to others with suitable technical skills for development. Thus, this can be an informal and rough sketch of a possible content presentation and interface screen design. The final product will evolve through further processes (prototyping, evaluation and development of the final product).

Table 3.1 Concept representation planning form

Concept representation planning tool
Name of a concept representation resource:
Velocity
Main concept(s):
Velocity
Related concept(s):
Acceleration
Displacement
Time
Properties:
Velocity, acceleration and displacement are vectors and they have +ve and −ve values indicating intensities and directions
Dynamic parameters:
Acceleration changes based on learner interaction between values of −1 to 1 m/s^2
Relationships:
Velocity changes in value from −100 to 100 m/s based on acceleration
Displacement changes between −20 to 20 km depending on velocity and time
Information:
Direction, how fast an object moves and effect of acceleration are shown as an animation (e.g., a car on the move)
Value of velocity is displayed numerically and at the same time represented on a velocity-time graph
Value of acceleration is displayed numerically
Displacements are shown in 'km' and shown on displacement-time graph

Important
Discipline specific concept knowledge are the foundation of one's theoretical thinking and his/her ability to intellectually operate within that discipline (e.g., solve problems or conduct a research in the way that scientists do).

When conceptualizing a storyboard, a designer will consider the following particulars:

- *General treatment and context for the concept representation*—In our example, the context will be that a learner changes the acceleration of a moving vehicle. Such a realistic context might not be always required, however, in some cases of concept resources, it can be useful to enable learners to relate a new concept to prior knowledge and experience.

- *Determine functional areas of the screen*—A screen of a concept resource might contain various functional areas, such as the functional areas where interactive elements are arranged, and functional areas where certain information is constantly displayed. In the case of our example, the screen is divided into four functional areas: v-t graph and d-t graph areas showing changes in velocity and displacement over time; a screen showing an animation that simulates movement of a vehicle on a road; and an area where numerical information about parameters, and interactive controls are displayed.
- *Determine modes of representation*—A designer must make a decision how to represent the relevant information. In our example, the movement of a vehicle is shown as an animation of a car moving along a road the value of velocity is presented as a car speedometer as well as a point on a line of v-t graph; acceleration is shown as a number between −1 and 1; and displacement is presented as a point on a line of a d-t graph.
- *Determine interactive elements*—A designer needs to make the decision how a learner will manipulate the dynamic parameter. Various possibilities exist for interaction, such as, sliders, text entry boxes, buttons, and clickable hot-spots. Emerging mobile technology also allows for finger driven interaction. There are even more innovative possibilities nowadays that allow interactions through gestures and body movement (e.g., Kinect or Myo). In our example, the dynamic parameter is acceleration, which is controlled by a learner with a slider that can be moved between maximum and minimum values.

3.4.4 Develop a Prototype of the Concept Representation Resource and Evaluate It

Until this stage, we see that these activities of the design can be comfortably carried out by educators. No technical skills are actually required, as all the work so far has included conceptualizing and sketching ideas. So, how to proceed further from this point on? The next step is to produce a prototype. In the formal sense, a prototype of software product is an important project management and client management tool. It provides a glimpse of what the final product will look like, including examples of screen design, interface elements and media. Once these are understood as acceptable by the project team and a client, and in some cases tested with real users, the production of a final product will proceed with the required amendments in place.

In case of collaboration between an educator and a developer (a multimedia designer, and in some cases a programmer supported by a graphics artist), a storyboard serves as a tool to clearly communicate requirements, ideas and expectations of that educator. Usually, an educator will meet with these professionals, and explain what he or she wants to have in the concept representation resources under development.

In case of holistic work by an individual educator who is able to carry on all of these technical activities, the development of a prototype might proceed without any storyboard being previously developed. In this case, an educator-as-designer would use the multimedia authoring tool as an aid in conceptualizations and planning, that is storyboarding and, at the same time, using the emerging design as a prototype.

In all of these scenarios, a prototype might be a useful tool to test ideas, obtain real users' feedback, and prevent spending time developing what might later not be accepted by a client or real users. The process of evaluating a prototype might be exceptionally useful to help a designer to further refine ideas through feedback from users. Several aspects are evaluated in such a scenario, including some of the following:

- Interface;
- Screen design;
- Suitability of content; and
- Effectiveness of presentation for learning uses.

3.4.5 Develop the Final Concept Representation Resource

The final step in the process is to develop the concept representation resource. This is technical task to execute what has been formalized though storyboarding and prototype development and evaluation. In the case of the Velocity example, the final concept representation resource is shown in Fig. 3.2.

When developing concept representation resources, specific delivery technology should be kept in mind. Nature of interaction and screen parameters strongly influence the design. For example, if we design a resource for an iPod, we need to keep in mind that this technology supports finger-driven interaction. The screen size is smaller than an iPad. Delivery technology also influences the kind of development approach used. For example, developing a resource for delivery via a computer might be effective with Adobe Flash. However, such a resource would not be functional on either iOS or Android based devices. HTML5 might possibly overcome this problem, and allow a resource to be deployed across multiple platforms.

Finally, once a resource is developed, it needs to be made available for accessing real users (teachers and students). This can be achieved in a number of ways. A resource can be delivered via course spaces such as those designed within Moodle or Blackboard Learning Management System (LMS) technologies. In such systems, a resource is uploaded in a space dedicated to a specific course. However, from an institutional perspective, this has limited impact because such resources are 'buried' in specific courses and students and teachers other than members of that course cannot access them at all. Since, there might be a need for an institution to

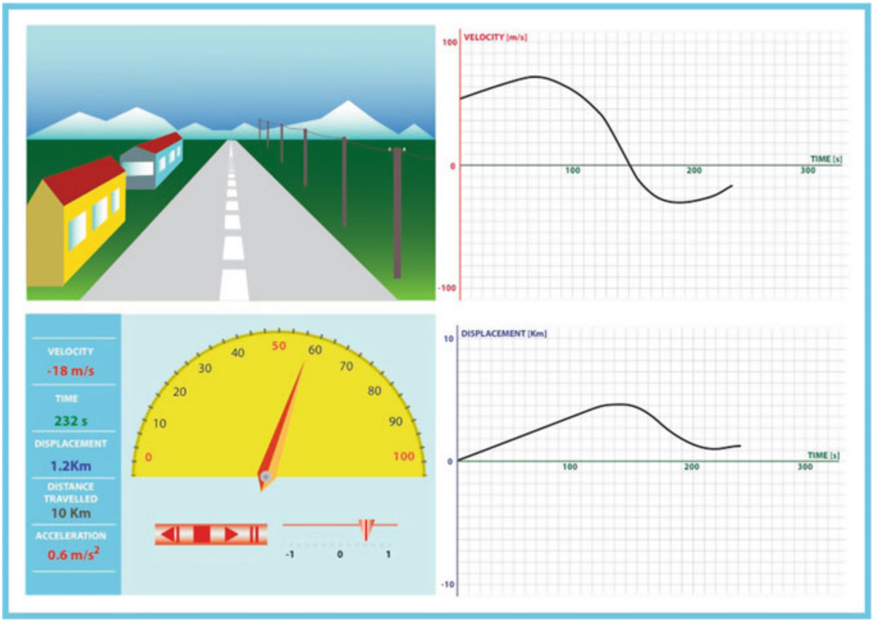

Fig. 3.2 'Velocity' concept representation resource

deploy a repository system that allows resources to be shared amongst individuals and used across platforms.[5] In addition, common for mobile learning content, resources can be deployed via systems such as App Store (Apple) or Play Story (Android). Furthermore, platforms such as Apple iTunesU allow for some content to be delivered to learners globally or within a subscribing institution.

> **Activity 3.3**
> *Let's go back to your concept of 'Heat' and a corresponding mind-map you developed. Examine this concept again and draw a sketch on paper of a conceptual resource that would allow a learner to examine this concept's properties, parameters and relationships, and refine your own misconception. Think about your Activity 3.2, and note how might your design support concept learning in the context of inquiry or problem solving you proposed.*

[5]More about repositories will be discussed in Chap. 8.

3.5 Examples of Concept Representation Resources

In this section of the chapter, a number of examples of concept representation resources developed by the author and his students are features. Each new design of a concept representation resource is an innovation in itself. There is no prescribed grammar of visual language, and the designers of such resources are required to be creative and innovative when developing each new representation. Therefore, these examples are just a few cases of concept representation resources and design possibilities.

3.5.1 Maximizing Content Presentable in a Minimal Screen Space: Machining Parameters

The concept representation resource presented in Fig. 3.3 was developed by the author and his colleague at a technical education institute in Singapore. The resource presents parameters, relationships and properties of concepts related to machining parameters in a precision engineering course. In particular, the resource represents content related to the 'Turning Machining' process. The resource has been used within an activity that requires students to consider a client's request for the machining of a certain work piece according to specifications presented in a supplied technical drawing. The final outcome is to develop a proposal for a client outlining the required machining time, and based on it, the most competitive cost for producing the work piece according to specified requirements. The teacher would also create an atmosphere where different groups of students work on this

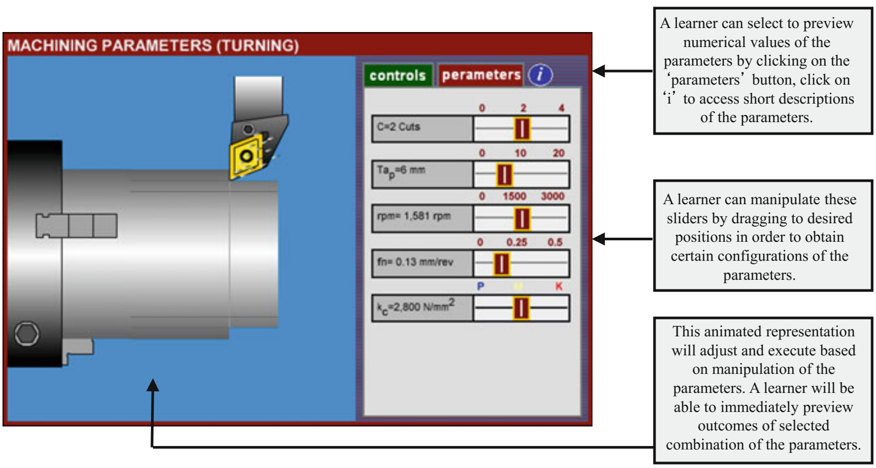

Fig. 3.3 'Machining Parameter (Turning)' concept representation resource (developed with a teacher from a technical education institute in Singapore)

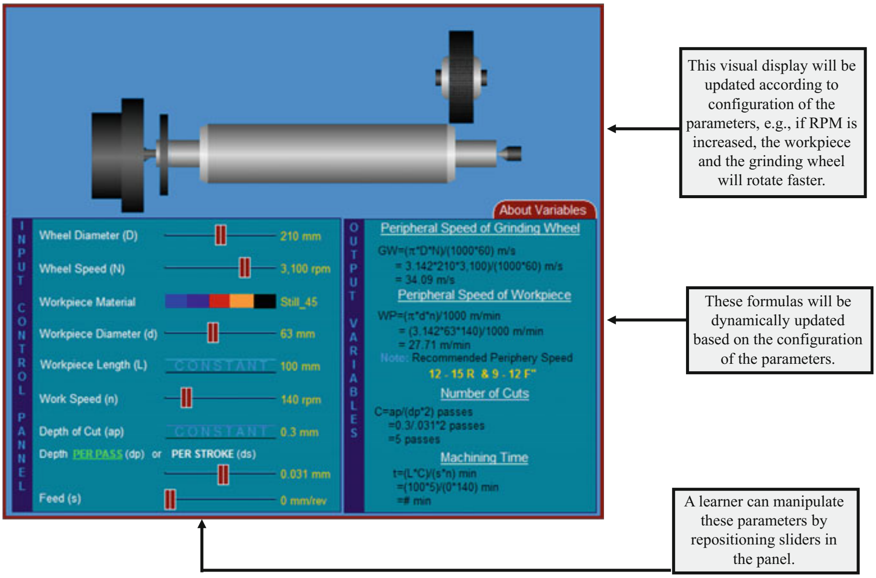

Fig. 3.4 'Machining Parameter (Grinding)' concept representation resource (developed with a teacher from a technical education institute in Singapore)

activity and compete for the most appropriate cost for the production based on optimization of the machining parameters.

The main purpose of this concept presentation is to allow learners to study fundamental concepts which they need for later understanding of computer numeric programming (CNC) and the use of real turning machines. What is interesting for this resource is that a huge amount of curriculum content is embedded in a single screen display. According to the colleague responsible for teaching that specific course, the concept representation resource includes content traditionally presented in more than 60 pages of a textbook used for his class, and equivalent to almost three months of teaching under traditional arrangements. The teacher involved in the design and use of this representation with his students highly appreciated this kind of material, and was motivated to continue collaboration with the author to develop an additional two resources for Milling and Grinding machining parameters. Figure 3.4 shows a screen from the Grinding machining parameters resource.

3.5.2 Concept Representation Resources in Non-conceptual Domain: Tenses and Four Tones

This book argues that curriculum content should include concept, as well as procedural and declarative knowledge, and emphasizes the use of all these forms of knowledge. Although this thinking that curriculum content should include concept knowledge might be more obvious in the context of science, mathematics, technical subjects, and social sciences, almost all domains have certain content that could be learnt through generalizing and abstracting rather than in declarative ways (e.g., by remembering facts and definition). In some subject domains, we might not be using terms and concepts, however, these domains also have certain key content that cannot be simply learnt in a declarative way, and some generalization and abstraction is required. What might more prominently differ between disciplines are specific ways of constructing generalization, e.g., scientific inquiry, content analysis of a literary text, or an investigation and constructing a theorem in mathematics.

For example, the resource in Fig. 3.5 demonstrates how this might work in the context of English language. This concept representation was developed for the use in an English as a second language class. It is a tool that helps learners conceptualize certain rules in language learning (tenses). A learner can input times into the two boxes on the screen and based on this configuration, the scenario will display a grammatically correct sentence in terms of tense and based on a selected verb (e.g., run, eat, sing, study and sing).

Figure 3.6 is an example from a Chinese as second language learning context. As we have already noted, language learning does not have concepts such as those commonly found in sciences, social sciences or mathematics. However, there are those kernels of these disciplines which are not declarative knowledge, rather, these are more abstract and difficult to learn. A teacher of Chinese as second language at a university in Hong Kong told the author that one of the kernels of her subject matter

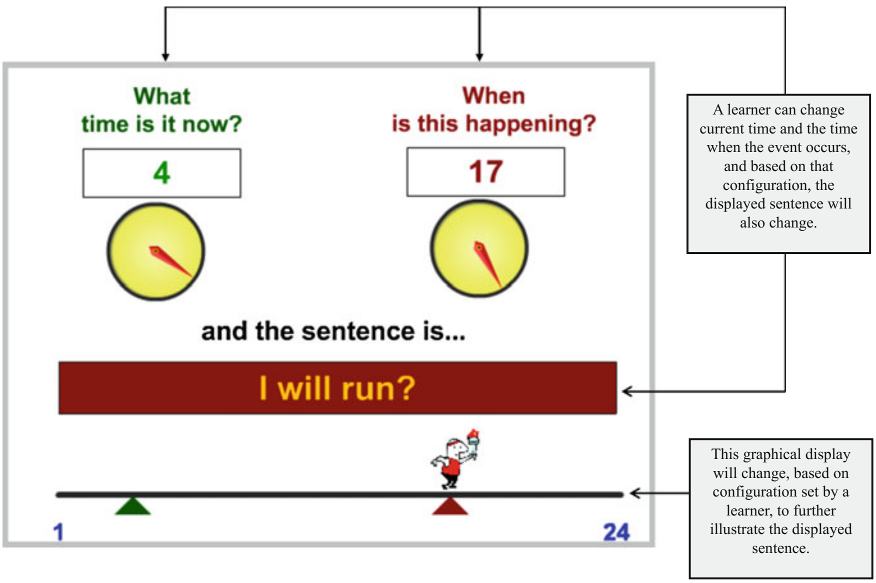

Fig. 3.5 'Multiplication of Fractions' concept representation resource (developed by the author and his student)

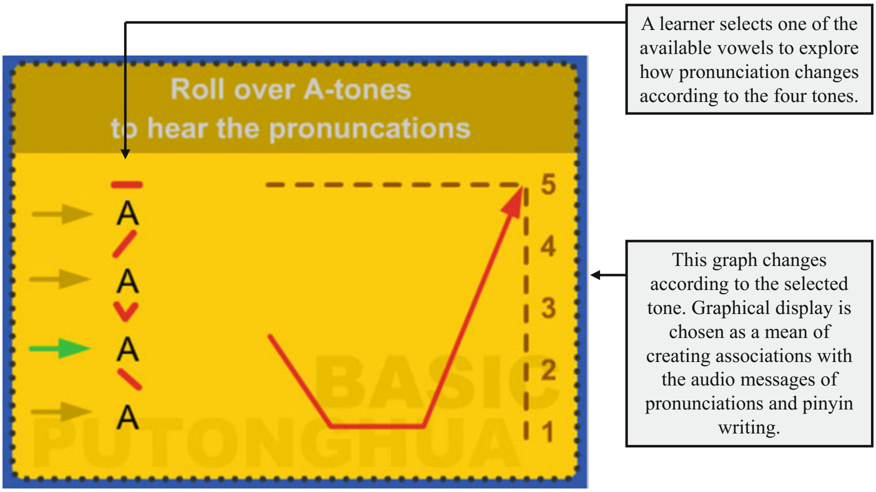

Fig. 3.6 'Four Tones' resources (developed by the author and a Chinese as a second language teacher)

is the four distinct tone intonations. Distinguishing between these tones, and becoming skilled to use them in reading so-called Pinyin, and later in speaking, is a critically important part of learning the Chinese language. The author subsequently worked with this teacher and designed a resource with the focus on the four tones.

3.5.3 Difficult to Visualize Domains: Algebra Blocks and Multiplication of Fractions

Some concept content of domains such as mathematics are difficult to visualize. In mathematics, for example, teachers are accustomed to mathematical expressions, symbols, formal diagrams and graphics, to the extent that prevents them to express their ideas through any different representational systems. However, using more intuitive, simpler and visual representational systems can greatly enhance mathematics learning. One such example is factorizing expressions of a form $x^2 + ax + b$. The concept representation called 'Algebra Blocks' is shown in Fig. 3.7 and designed to help learners understand and perhaps visualize independent factorization of expressions.

Figure 3.8 shows another Mathematics example, a representation of the multiplication of fractions. Multiplication is represented as two sides of a rectangle. Each side represents one whole. The repositioning of sliders will fraction sides, and the final product of the multiplication of two fractions will be represented as a shaded portion of the whole.

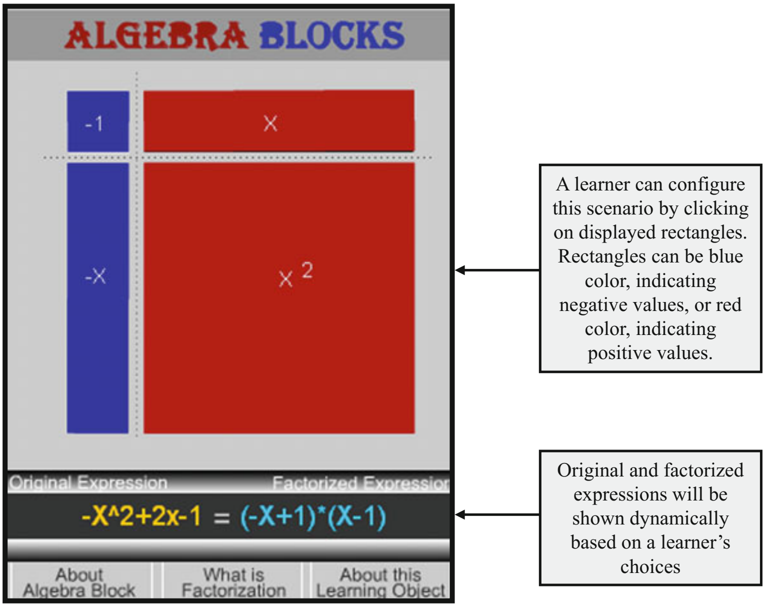

Fig. 3.7 'Algebra Blocks' concept representation resource

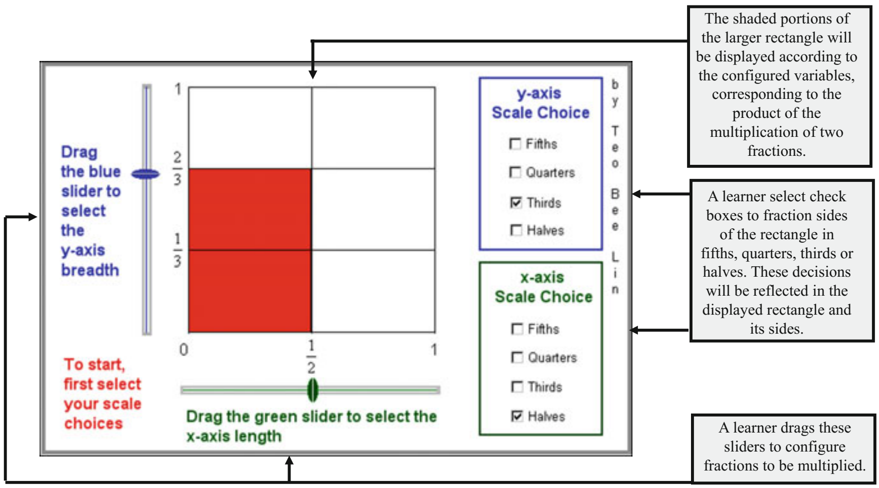

Fig. 3.8 'Multiplication of Fractions' concept representation resource (developed by the author and his student)

3.5.4 Teaching Young Learners to Generalize: Drying Rate

The concept of representation resources presented in Fig. 3.9 was designed with an intention to engage young learners to learn about the processes of generalization and abstraction and in that way, develop their disposition to approach concept representations in a systematic way during their learning. Developing such disposition is a kind of literacy that contemporary education should develop for learners today. Schools teach students from an early age how to read and write, listen and speak, but more attention should be given to viewing and representing the skills required to effectively consume and communicate with emerging representational forms.

This resource is not discipline specific. It is a general representation of something that young learners might encounter in their real life. However, the way they would need to approach this resource in order to understand it, is the same as for any discipline specific concept representation. Young learner's cognitive load is freed from any burden in trying to understand the disciplinary content and, in such a way, they can focus purely on processes, understanding properties and relationships, and subsequent generalizing and abstracting.

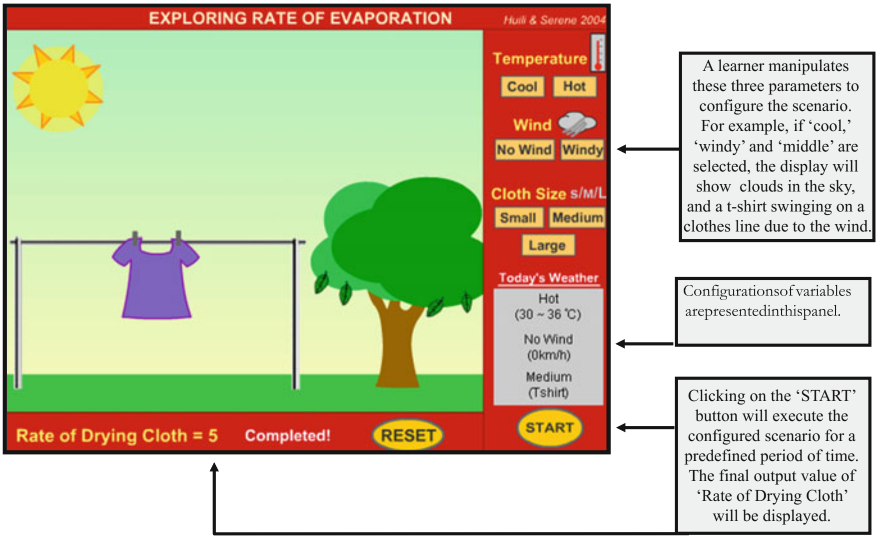

Fig. 3.9 'Draying Rate' representation (developed by the author and his student)

3.5.5 Simulations and Concept Learning

A simulation[6] is a specific form of digital media that might be integrated into a concept representation resource or in a practice resource. It displays a real system, process, event and object, unlike those representations which address more abstract concepts. Often, simulations are designed to enable learners to understand how a corresponding real thing works, practice certain procedures, and experiment. A simulation can be used to represent concept knowledge. However, a simulation might also be used to support procedural learning. When used in a concept representation resource, a simulation can represent a system and its parts and properties, and allow a learner to learn and understand underlining properties, relationships and develop abstract concepts. An example of such concept representation resource is presented in Fig. 3.10.

The upper part of this concept representation resource displays two cross-sections of a centrifugal water pump. A learner can manipulate a set of parameters, and explore how these interact and what they mean (by noting changes in number of impellers and increases in revolutions), and how these affect pressure produced by the pump. The bottom part of the concept representation displays a scenario showing a system where a pump is used to lift water to a certain height for filling reservoir position at the top of a building. A learner can examine relevant parameters and develop an understanding of the relationship. These understandings are then applied in a project (a learning activity) requiring learners to design a water system to be used in a specific building configuration that their teacher set.

Figure 3.11 shows another interesting example of a concept representation resource that contains some real-life elements included in its display. This example from a 'Chemistry' course was designed to help students to understand and learn the concept of 'Reaction Rate'. A learner can manipulate the particle size of a marble to be exposed to a chemical contact/reaction with acid, and examine time taken for the reaction to take place.

3.6 A Study of Design of Concept Representation Resources

Over the last several years, the author has engaged in investigating the aspect of design of concept representation resources (previously called 'concept models'). Two aspects of design were identified and studied: (a) Presentation Design and (b) Design for Learning Uses. Presentation design addresses features and

[6]The term 'simulations' should not be used for anything that is visual and interactive. More than anything, a simulation is a kind of media, not specifically a kind of digital resource for learning. For us in this book, the kinds of resources for learning are associated with specific forms of curriculum content knowledge, e.g., procedural or concept knowledge, and various media types that can be integrated into the design of such resources.

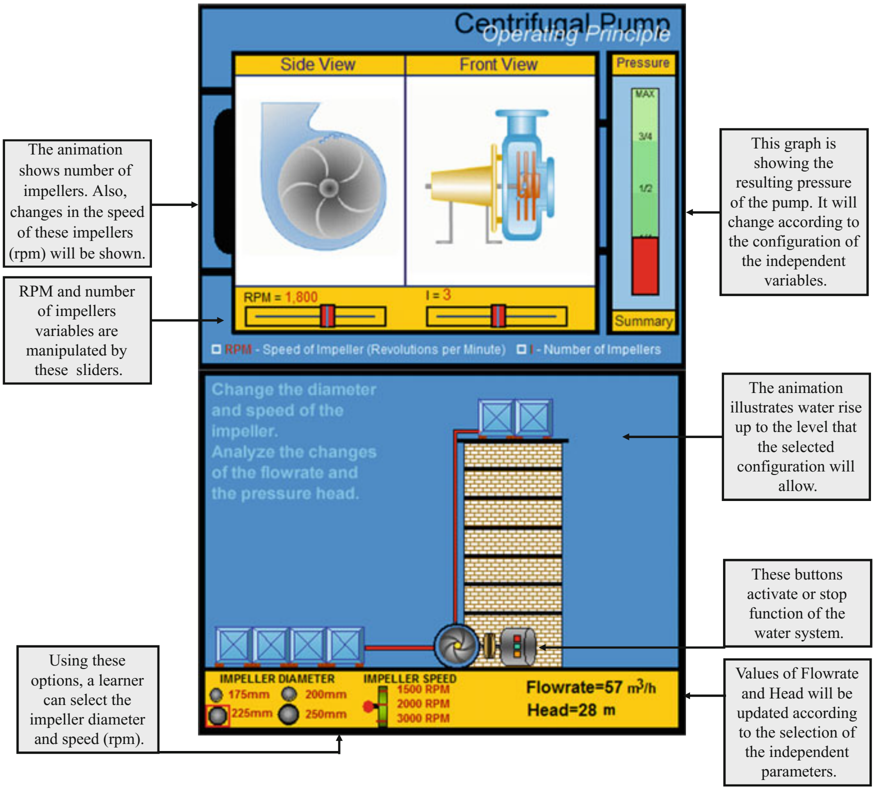

Fig. 3.10 'Centrifugal Water Pump' concept representation resource (developed in collaboration with a teacher teaching 'Mechanical Maintenance' course at a technical education institute in Singapore)

possibilities for arranging various media elements on a screen. Design for learning uses, on the other side, refers to aspects of design that would support later reusability in the context of learning-centered activities such as inquiries and problem-solving. In this section of the chapter, discussion of presentation design will be provided. Discussion of the design for learning uses will be provided later in a different chapter.

A concept representation is an important educational multimedia resource that, when appropriately designed and used, can contribute to improvements in concept learning. Currently, there is a lack of empirically-developed guidelines on how to design technology-based concept representations for educational purposes. Although some guidelines for the design of representations for multimedia learning exist (e.g., Mayer 2001), there are almost no guidelines in relation to the presentation design of concept representation resources and other forms of digital resources for teaching and learning. At the same time, it is important to note that

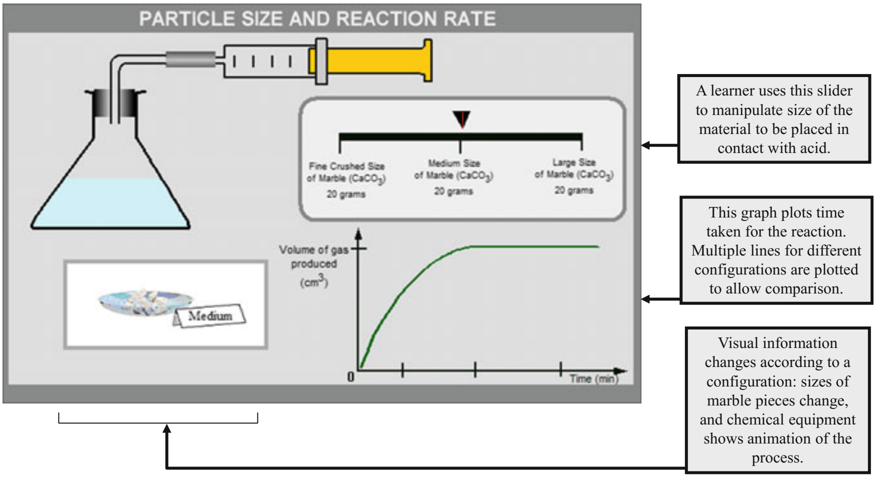

Fig. 3.11 'Particle Size and Reaction Time' concept representation resource (developed by the author's students)

even the most effectively designed concept representation might not be useful unless it is properly designed for integration in learning activities.

The author previously conducted a study of presentation design of concept representation resources. A number of recommendations for presentation design are provided. These are explicated based on a study involving a review of a collection of concept representation resources.

3.6.1 The Study of Presentation Design

The recommendations developed in the study emerged from a review of a collection of 54 concept representations and their design characteristics (Churchill 2014). Five expert reviewers conducted the review. The reviewers were identified and selected based on the following criteria relevant to the objectives of the projects:

- Formal qualification related to areas such as instructional design, e-learning or information technology in education;
- Experience in the design of multimedia content/learning objects;
- Teaching experience in a specific discipline and previous use of learning objects in supporting discipline-specific learning; and
- Willingness to participate in the study as an expert reviewer.

The researcher also attempted to engage reviewers from across educational institutions including a primary and a secondary school, a technical education institute and a university. The reviewers also ranged in respect to their teaching disciplines. The reviewers included:

- A Geography secondary school teacher with a Master Degree in information technology in education qualification;
- An English language primary school teacher with a Graduate Diploma in E-learning Instructional Design qualification;
- An Engineering lecturer from a technical education institute with a Graduate Diploma in E-learning Instructional Design qualification;
- A university professor with expertize in IT in Education (previously worked as an Economics teacher in a school); and
- A university professor with expertize in Multimedia Design (previously worked as a Mathematics and Science teacher in a school).

The expert reviewers independently previewed each of the 54 concept representation resources from the collection provided. The reviews were recorded by using a form created for the purpose of the study. This form is presented in Fig. 3.12. The form was developed in partial consideration of certain issues from the 'cognitive theory of multimedia learning' (Mayer 2001) and based on a discussion between the reviewers. The cognitive theory of multimedia learning provides a set of empirically developed guiding principles for the design of educational multimedia for delivery via computer screens. Issues considered in developing the form were:

- *Multimedia principle*—What is the predominant mode of representation for the essential content of this concept representation (e.g., visual, textual, animation, auditory)?
- *Principles for managing essential processing (navigation)*—Describe characteristic structure and navigation (e.g., single or multiple screen, user-paced or automatic, hierarchical or linear navigation, physically and temporally integration of modes).
- *Principles for managing extraneous processing (interactivity)*—Describe the interactive features used to manipulate the represented concept (e.g., slides, buttons, and clickable hot-spots).
- *Principles for reducing extraneous processing*—How was the extraneous content used (e.g., use of colour to highlight the organization of the essential content)?

For example, a category in the form titled 'Modes of Representation' was influenced by the 'Multimedia Principle,' while the 'Content Structure' category was influenced by the 'Principles for Managing Essential Processing'.

Data from the completed forms were converted to numerical values according to the following schema:

- Scores for Pedagogical Quality (PQ) included: 1 (very low and low quality), 2 (average quality) and 3 (high and very high quality);
- Scores for Multimedia Quality (MMQ) included: 1 (very low and low quality), 2 (average quality) and 3 (high and very high quality);

Review of a Conceptual Representation Resource Form

Reviewer:

Title of the conceptual representation resource under review:
Brief description of the conceptual representation resource:

Pedagogical quality of the conceptual representation resource				
☐ Very low quality	☐ Low quality	☐ Average quality	☐ High quality	☐ Very high quality

Multimedia quality				
☐ Very low quality	☐ Low quality	☐ Average quality	☐ High quality	☐ Very high quality

Interactivity Features						
☐ Text-input boxes	☐ Buttons	☐ Hot spots	☐ Pull-down menu	☐ Roll-over	☐ Sliders	☐ Target area

Content structure		
☐ Single screen	☐ Linear sequence of screens	☐ Hierarchical structure of screens

Screen Display Area		
☐ < 640 by 480	☐ ≥ 640 by 480	☐ ≥ 800 by 600

Modes of representation	
Modes used in the design	The predominant mode
☐ Text [labels and values only]	☐
☐ Text [sentences explaining content]	☐
☐ Visuals – drawings, diagrams and illustrations	☐
☐ Visuals – photographs	☐
☐ Video	☐
☐ Animation	☐
☐ Audio	☐

Any other comment about the conceptual representation resource

Fig. 3.12 Form used in the review of concept representation resources

- Scores for Interactive Features (IF) were obtained by adding the number of unique interactive elements used in the design (range from 1 to 7);
- Scores for Content Structure (CS) included: 1 (single screen), 2 (linear sequence of screens) and 3 (hierarchical structure of screens);
- Scores for Screen Display Area (SDA) included: 1 (less than 640 by 480), 2 (greater or equal to 640 by 480) and 3 (greater or equal to 800 by 600); and
- Scores for Modes of Representation (MR) were obtained by adding the number of different representations used in design, ranging from 1 to 7.

The reviewers were required to provide their independent assessment for 'Pedagogical Quality' and 'Multimedia Quality' respectively. Scores of all the reviewers were added together to obtain the final values (ranging from 5 to 15). In addition, the reviewers were required to indicate the predominant mode of representation for each of the concept representations. The other measures were objective (CS, SDA, MR and IF) and were pre-inserted into the forms for each of the resources in the collection. The data were processed using SPSS statistical analysis software to obtain values for correlations between various measures. Outcomes are shown in Table 3.2.

Interpretation of correlation coefficients was informed by Cohen (1988), who provides the following guidelines for effect sizes: small effect size, $r = 0.1 - 0.23$; medium, $r = 0.24 - 0.36$; large, $r = 0.37$ or larger. In addition, statistical analysis was applied to obtain differences in the means in pedagogical quality between resources with visual as the predominant mode of representations and other resources.

Processing and analysis of data resulted in a set of recommendations for presentation design. The analysis of the data was conducted and conclusions reached in collaboration and discussions with the reviewers. The team discussed contradictions and differences in opinions in order to interpret the data and develop assertions and articulate final recommendations. The team also articulated some general observations about the features of the designs, and some unique aspects of design that hinted at pedagogical quality. The following categories of recommendations were explicated in the study: present information visually, design for interaction, design a holistic scenario, design for a single screen, design for small space, use audio and video only if they are the only option, use of color in moderation, avoid unnecessary decorative elements, design with a single font, and use frames to logically divide the screen area.

Table 3.2 Summary of correlation coefficients and *p*-values

Measures	*r*	*p*
PQ/MMQ	0.079	0.57
PQ/CS	−0.12	0.391
PQ/SDA	−0.017	0.905
PQ/MR	0.132	0.342
PQ/IF	0.454	0.001

3.6.2 Recommendations for Presentation Design

A major aim of this study was to develop recommendations by linking features of design to the perceived pedagogical quality of the concept representation resources. The author's intention at this stage was to provide sufficient description of the recommendations in order to allow readers to examine whether these are useful in their own educational media development practices. The following recommendations emerged:

- *Present information visually*—The study results showed a small correlation between the level of perceived pedagogical quality (as judged by the reviewers) and the quantity of modes of representation ($r = 0.132$, $p = 0.342$). However, when the pedagogical quality of resources with visual as the predominant mode of representations ($N = 41$, $M = 10.24$, $SD = 3.277$) was compared to that of learning with other predominant modes ($N = 13$, $M = 7.62$, $SD = 2.959$), significant differences were observed ($t = 4.6$, $p = 0.013$). These differences were also substantive as indicated by a large effect size ($d = 1.48$). The differences suggested that the content of a concept representation resource should be presented predominantly through visual representations (e.g., photographs, illustrations, diagrams, graphs, colors, icons and symbols). Sometimes, the same information can be presented in a number of modes simultaneously (e.g., as text, visually and via audio). However, results strongly suggested that visuals should be the central mode of representation. Representing the same information through multiple modalities should be carefully managed [see redundancy principle (Mayer 2001)].
- *Design for interaction*—The result of this study showed that there was a large correlation between pedagogical quality and the total number of interactive features used in the designs of the concept representations under review ($r = 0.454$, $p = 0.001$). This suggests that the more interactive features a concept representation has, the higher its pedagogical quality. Relationships and properties should be displayed in interactive ways to allow the user of a concept representation to manipulate parameters and observe outcomes (e.g., by manipulating sliders, clicking on buttons, or inputting text/numbers). Outcomes of the manipulation can be presented in a single mode or in several modes at the same time (e.g., as a number or a graph); however, visuals emerged in this study as the most pedagogically effective representation.
- *Design a holistic scenario*—Design elements should be arranged in such a way that some of the content are integrated into a holistic presentational scenario depicting the concept that is represented. In other words, all areas of the screen need to be integrated into a holistic scenario that supports multimedia representation of a concept. This recommendation emerged from the observation that content structure had a small correlation with pedagogical quality ($r = -0.12$, $p = 0.391$). Distributing content across multiple screens will add complexity to

the development of a concept representation resource without any significant increase in pedagogical quality.

- *Design for a single screen*—A concept representation resource can be designed for presentation in a single screen. Single screen presentation is likely to allow a learner to have a holistic focus on all elements of the required concept knowledge. Further, a single screen is likely to enable a learner to manipulate relationships and properties, and to access the outcomes of this manipulation all in one place. At the same time, a single interactive screen can be easily meshed with other media into structures such as web pages. Content structure had a small correlation with pedagogical quality. The review provided an additional hint that concept representation resources designed on a single screen might be sufficiently effective in terms of the pedagogical quality, and designing for presentations in more than one screen might not have any positive effect on pedagogical quality; rather, this might have a negative effect by causing split-attention and increased 'Cognitive Load' (see Mayer 2001).
- *Design for small space*—The design of a concept representation resource should utilize only the screen space necessary to present all the required information, properties, relationships and interactive elements. From the review, it was observed that most of the concept representation resources were designed in a screen space that does not exceed 640 by 480 pixels. The data from the study did not produce any significant correlation between pedagogical quality and sizes of the screen display area ($r = -0.017$, $p = 0.905$). This recommendation might lead to two important implications. Firstly, a smaller screen area would enable students to concentrate their attention on a smaller space, thus, reducing split-attention. Secondly, a resource designed for a small screen might later serve as a media object that can be embedded into larger screen displays such as in blog posts, instructional products and presentation slides.
- *Use audio, animations and video only if they are the only options*—Audio should only be used if it is effective for a representational purpose or to enhance realism when required (e.g., a specific sound indicating a faulty machine), or to offload cognitive processing from the visual channel [see modality principle (Mayer 2001)]. Similarly, video should only be used when, for example, the manipulation of relationships requires different segments from a video to be presented based on the configuration of parameters. Often, content from a video might be presented as several images of the key frames, with short blocks of text explaining each of the frames [which might support the temporal contiguity principle (Mayer 2001)]. Qualitative observations in the study suggested that the use of video, animations and audio had no effect on pedagogical quality; rather, these only increased the complexity of a concept representation in terms of effort required for learning, as well as in terms of efforts required for development of a concept representation resource.
- *Use color in moderation*—Another qualitative observation suggested that in order to present the content clearly, color should be used in moderation. On the

other hand, quantitative data suggested that there was an insignificant correlation between pedagogical quality and the multimedia quality of a concept representation resource design ($r = 0.079$, $p = 0.57$). Often, color was found in the reviewed cases of concept representation resources to be effective when used as visual content and to connect related information (e.g., connecting a positive numerical value displayed in red with a red bar on a bar graph). Different shades of color can be effectively used, but the use of sharply contrasting colors must be avoided. The focus should be on the simplicity and clarity of presentation and support for learning, rather than on the pursuit of gratuitous artistic and multimedia beautification of the display.

- *Avoid unnecessary decorative elements*—This is another recommendation emerging from understanding that there is no correlation between pedagogical quality and multimedia quality. Unnecessary decorative elements can add complexity to the representation and result in increased extraneous cognitive load (Mayer 2001). They should be used in moderation, or not at all. All elements of the design should serve the purpose of representing a concept (or should facilitate this representation) and allow a student to manipulate its properties and explore relationships. In addition, cartoon-like characters should be avoided unless they serve some representational purpose. Many designers assume that cartoon-like characters will motivate students by making learning fun; however, such graphics are less than productive for learning. For Collins (1996), designers should not assume that fun is a desirable component of presentation, because there is a risk that students might not take such learning seriously; thus, a 'fun' presentation might impede learning. Motivation lies in a learning task that engages a student in the use of a concept representation resource, rather than in the resource itself. A concept representation resource is a strategy for effective representation of educationally useful concepts, and unless its design elements support this representation, they should not be included.
- *Design with a single font*—In order to keep the presentation simple, a single font style should be used (e.g., Arial font in different sizes, shades and styles). The same color fonts can be used to relate pieces of information. Using multiple font types might increase extraneous cognitive load and have a negative effect on learning. Similar to the previous two recommendations, this recommendation is connected to the absence of a correlation between pedagogical quality and multimedia quality.
- *Use frames to logically divide the screen area*—Review of the collection of concept representation resources indicated that frames can be useful in dividing the presentation screen into functional and logical areas and groupings. For example, interactive elements such as sliders and buttons can be grouped together in one area of the display, while another area can be used to display output information. Such areas might support visual attention (as a student focuses attention on one framed area at a time) and positively affect the utility of the essential cognitive load required to process information (Mayer 2001).

3.6.3 An Example of a Concept Representations Resource Design Reflecting the Recommendations

The concept representation resource featured in Fig. 3.13 was designed to support secondary school students' learning of the concept of a volcano. This concept includes issues such as lava types, how they affect the structure of eruptions, and the effects of eruptions on the environment.

A learner can select one of the following types of lava: runny with little water, runny with lots of water, sticky with little water or sticky with lots of water. After selecting the lava type, the learner will be able to explore the structure of an eruption and the effect that it has on the environment. This will allow the learner to compare changes in structure and differences in the effects between different volcanoes and eruption types.

Design features of this concept representation illustrate the usefulness of the recommendations discussed here. This is elaborated in Table 3.3, which links each of the recommendations to some specific feature of the 'Volcano' concept representation resource. The design of this concept representation resource reflects most of the recommendations.

Activity 3.4
Look back at the paper-based design of the concept representation of 'heat' which you articulated in Activity 3.3. Carefully consider the Design for Presentation Recommendations provided in this section, and redesign your design to incorporate these prescriptions. Then, create a new table such as Table 3.3*, and fill it in with information related to your own design to indicate how it incorporated the Recommendations.*

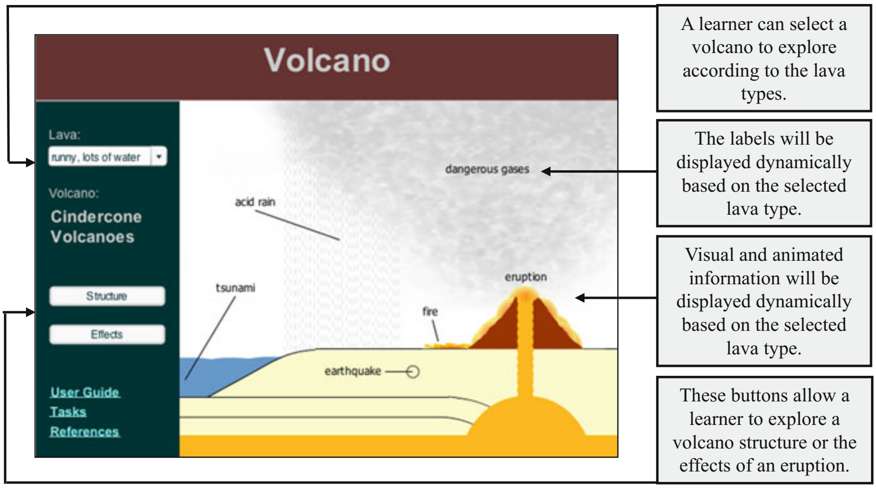

Fig. 3.13 'Volcano' concept representation resource (developed by the author's student)

Table 3.3 Design features from the "Volcano" concept representation resource (crr)

Recommendations		Design features from the "Volcano" concept representation resource (crr)
Design for presentation	• Present information visually	• Information in the crr is presented mostly visually (e.g., cross-section of the volcano, and changes in eruptions). Text is used for buttons, labels, and instruction
	• Design for interaction	• The crr allows a learner to manipulate parameters through a pull-down menu (to select type of lava for exploration). Outcomes of manipulations are presented visually and numerically (e.g., cross section of the volcano, effects and animation of the eruption)
	• Design a holistic scenario	• Elements such as the cross-section of the volcano and the effects are arranged in a way that integrate into a single scenario
	• Design for a single screen	• Content of the crr is presented in a single screen
	• Design for small space	• The crr is designed for effective presentation in a 640 × 480 pixel screen area
	• Use audio and video only if it is the only option	• No audio or video content is present in the crr. Although audio could add some realism (e.g., explosion in eruption of the volcano), its presence is not necessary. Animation is used to add illustrative realism to the visual output
	• Use color in moderation	• Color use is limited in the design. Colors include gray, blue, maroon, black, green and yellow
	• Avoid unnecessary decorative elements	• No decorative elements are used in the crr. All elements are related to essential content
	• Design with a single font	• Only Arial font is used in the crr
	• Use frames to logically divide the screen area	• The screen is divided into functional areas. Left side of the screen contains control elements (pull-down menu, hot spots and buttons). Right side of the screen displays essential content

3.6.4 Call for Further Empirical Studies

The development of a concept representation requires: (a) the ability to identify a suitable concept from a discipline for development into a representation, (b) deep knowledge of the concept that is to be represented, (c) an understanding of pedagogically appropriate ways of representing the concept, (d) creativity in representing through interactive multimedia art, and (e) an understanding of an effective design for delivery via a specific technology. The study of the presentation design features of a concept representation resource resulted in an understanding of a number of useful recommendations as follows: present information visually, design for interaction, design a holistic scenario, design for a single screen, design for small space, use audio and video only if they are the only options, using color in moderation, avoid unnecessary decorative elements, design with a single font, and use frames to logically divide the screen area. While these recommendations for design for presentation should prove useful to designers of concept representations and other forms of digital resources, other aspects of design must be explored further. Future study might further explore links between pedagogical quality and specific design features. For example, correlation(s) between specific interaction used in the design and pedagogical quality might lead to further recommendation. In addition, more might be done in relation to understanding specific multimedia screen arrangements and effects on the cognitive effort required for conducting visual searches.

The study reported here used perceived pedagogical quality as a key measure to understand the effective features of a multimedia design. Further study might attempt to replicate this procedure. Rather than using a measure of perceived pedagogical quality as given by expert reviewers, measured achievement of learning outcomes is an option. However, this would require a huge amount of effort to collect such data. A large number of students would be required to use a significant number of digital resources for learning and then be tested to obtain such measures. Furthermore, this might require that attention be given to an additional variable of an activity; that is, the specific ways in which a digital resource for learning was used in a learning context when data were collected.

Lately, there has been an increase in concept representations and other digital resources available via mobile technologies such as iPods. Consideration needs to be given to design when a concept representation resource is to be delivered via devices whose screen size and interactions are different as compared to computers. Furthermore, these recommendations for design for presentation do not provide ideas regarding instructional uses of a concept representations and, therefore, although useful to designers, are of little use to teachers. Applying these recommendations alone will result in a concept representation design that is not necessarily optimized for instructional use. Further inquiry is required in order to develop more comprehensive recommendations that incorporate specific features of design for small screen and learning uses. The author has conducted such inquiry, and it is reported in the later chapter that discusses mobile technology and digital resources for learning.

Activity 3.5

Why do seasons change? What is your concept of season change? Begin by asking yourself what you understand about changes of seasons. Bring together all the parameters that affect season change. Approach some resources such as books and Internet sites. However, be careful, there are a lot of misconceptions about causes to season changes in books and Internet resources. Some of your misconceptions might also prevent you from articulating a cognitive resource, which will help you to design a conceptual *representation resource. Articulate your design as a single slide (you can use any graphic design or presentation software, unless you are skilled to use some kind of authoring or programming tool) to show your ideas for design. Refer to the design process introduced in this chapter, as well as to the design recommendations provided. Make sure you are able to discuss how these are integrated in your design.*

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