THE MEETING OF GESTALT AND COGNITIVE LOAD THEORIES IN INSTRUCTIONAL SCREEN DESIGN

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Abstract: Without doubt Gestalt Theory has formed an important basis for many aspects of educational visual screen design. Despite the familiarity many computer screen designers claim with it, Gestalt Theory is not a single small set of visual principles uniformly applied to by all designers. In fact, it appears that instructional visual design literature often deals with only a small set of Gestalt laws. Recently Gestalt literature was consulted to distil the most relevant Gestalt laws for educational visual screen design, resulting in eleven laws being identified. In this paper these laws are discussed in terms of the Cognitive Load Theory, (CLT), which has been used with considerable success to improve instructional design. The usefulness of the combined perspectives drawn from the Gestalt Theory and CLT for educational visual screen design were applied to the redesign of an instructional multimedia application, WoundCare, designed to teach nursing students wound management. The evaluation results were encouraging. Both the new design and the value of applying the eleven Gestalt laws and CLT principles to improve learning were strongly supported. However, many aspects of applying this combination of theories to educational interface design remain unclear and this forms a useful direction for future research.

1 INTRODUCTION

Gestalt theory has been considered as one of the foundations for instructional screen design. It is generally accepted Gestalt theory may be used to improve educational screen design and thereby improve learning (Preece et al., 1994, p.78-80). Gestalt laws explain how the individual elements organise fields from the environment (Koffa, 1935). Boring (1942) states "in 1933 Helson extracted 114 law of Gestalten. All but half a dozen of these laws are applicable to visual form." Many of the laws are very closely related or overlap, and it is often very hard to distinguish between them. We have identified eleven laws that represent the major aspects of Gestalt Theory for instructional multimedia interface design (Chang, Dooley & Tuovinen, 2001).

Cognitive Load Theory has developed over the last decade and a half (Sweller, 1988; Sweller, van Merrienboer & Paas, 1998) to be an important empirically founded theory of instructional design. It has direct implications for educational computer screen design, as well as many other aspects of instruction.

In this paper we present a synthesis of these formidable theories, seeking to gain a greater understanding of effective screen design for education. The combined Gestalt and Cognitive Load principles were applied to the redesign of an educational multimedia program, WoundCare, and we then evaluated the quality of interfaces for complex learning material in order to achieve effective learning environments with substantial educational value. This paper is an account of how useful these principles were in a particular multimedia screen design and by extrapolation what

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benefit other designers may gain from using these design principles.

Table 1: 11 Gestalt Laws for Screen Design

Gestalt Law	Meaning
Law of Balance	A psychological sense of equilibrium, or balance, is usually achieved when visual "weight" is placed evenly on each side of an axis (Lauer, 1979; Preece et al., 1994, p.79-80).
Law of Closure	Our minds will tend to close gaps and complete unfinished forms (Fisher & Smith-Gratto, 1998-99; Fultz, 1999).
Law of Continuation	Continuation is the eye's instinctive action to follow a direction derived from the visual field (Fultz, 1999).
Law of Figure-Ground	It is natural for humans to distinguish between a foreground and background.
Law of Focal Point	Every visual presentation needs a focal point, called centre of interest or a point of emphasis. This focal point catches the viewer's attention and persuades the viewer to follow the visual message further (Lauer, 1979).
Law of Isomorphic Correspondence	All images do not have the same meaning to us, because we interpret their meanings based on our experiences.
Law of Prägnanz (Good Form)	Fultz (1999) defined Prägnanz (Good Form) as "a stimulus will be organized into as good a figure as possible." Good form is a simple design or a symmetrical layout.
Law of Proximity	Items placed near each other appear to be part of a group (Fisher & Smith-Gratto, 1998-99). Viewers will mentally organise closer elements into a coherent object (Fulks, 1997; Fultz, 1999).
Law of Similarity	Similar objects will be counted as the same group, (Fisher & Smith-Gratto, 1998-99).
Law of Simplicity	The designer should consider how to arrange elements and visual objects in a simple manner. Complex screen design will puzzle the learner, and can lead to misunderstanding, increasing the difficulty of learning (Fisher & Smith-Gratto, 1998-99).
Law of Unity	According to Lauer (1979) "Unity implies that a congruity or arrangement exists among the elements in a design; they look as through they belong together, as though there is some visual connection beyond mere chance that has caused them to come together."

2 11 GESTALT LAWS APPLICABLE TO INTERFACE DESIGN

In this section, we list the eleven laws of Gestalt Theory we identified as visual layout rules for instructional multimedia interfaces (Chang, Dooley & Tuovinen, 2001; Chang, Wilson & Dooley, 2003), which have significant implications for multimedia screen design. Details of each individual law were described in the paper "Toward Criteria for Visual Layout of Instructional Multimedia Interfaces" (Chang, Wilson & Dooley, 2003). A summarised version is presented in Table 1.

3 COGNITIVE LOAD THEORY

The Cognitive Load Theory takes as its basis the human cognitive architecture and its implications for learning and instruction (Sweller, van Merrienboer & Paas, 1998; Paas, Renkl & Sweller, 2003). The human cognitive architectures is thought to consist of three principal components, the sensory memory, the working memory and the long-term memory. It is the limited capacity of the working memory (WM) and the huge capacity of the long-term memory that provide the basis for the cognitive load theory. With a very limited working memory the incoming information can only be dealt with a few items at a time, but as these items are combined into knowledge networks, called schemas in the long-term memory (LTM) they may be recalled and utilised as either individual elements or clusters of

elements, called chunks. It is this combining of elements for storage in the LTM and later efficient retrieval and utilisation in the WM that gives humans the power of the apparently prodigious feats of intelligence. Combined with automation of many cognitive processes with extensive practice, which also will consume minimal WM capacity, schema development and utilisation provide humans with our remarkable cognitive capacities.

In studying what the implications of this way of approaching human learning and instruction might suggest for better education many significant effects or principles have been identified in the CLT frame of reference. Some of the most relevant to educational screen interface design aspects are listed in Table 2 (Tuovinen, 2000; Sweller, 1999).

4 SYNTHESIS OF GESTALT AND CLT

A number of the Gestalt Laws and CLT principles or aspects are very clearly related together. These are discussed first in this section. However, there are some aspects of each theory that do not appear to be closely linked together and they are identified at the end of this section.

4.1 Gestalt and CLT theory overlaps

The Law of Closure seems to be very closely related to a key aspect of CLT, the desirable elimination of split-attention by integration of multiple relevant sources of information on a page or a screen. In Closure multiple individual items are related together to make sense of the pattern involved, and in a similar way integration of text and graphics, for example, in CLT can make the material more intelligible.

The Law of Continuation depends on establishing a pattern for the observer to follow in the visual field. In the CLT context such patterns are highlighted in principles such as the worked examples approach to student practice of new procedural information. The extra guidance involved in students reading through numerous problems and their solutions before attempting their own problem solving has been shown to be far more effective than problem solving practice alone for novice learners with minimal prior knowledge in a given field (Tuovinen & Sweller, 1999).

Table 2: Examples of CLT Principles

CLT Principle	Meaning
Goal-free effect	Search in problem solving practice may be reduced by changing conventional problems with specific goals to reach after many steps, to simpler, more general explorations of the content area, leading to better learning, due to increased capacity in WM for schema development.
Worked example effect	Instead of students immediately practicing by solving problems after a lesson, they study the solutions to many similar example problems, before attempting own solutions. Studying the worked examples reduces the search involved in means-ends analysis problem solving practice, leading to more effective schema development.
Split-attention effect	Difficulties of students needing to study physically separated materials, can be overcome by integrating learning materials, such as graphics and text.
Redundancy effect	If an existing presentation, such a circulatory diagram with arrows indicating blood flow direction, already conveys adequate information, physically integrating more textual information with the diagram, such as explanatory text linked to the graphics, may cause problems for learning, due to learner processing of unhelpful material in limited WM.
Focusing attention by flashing	Flashing graphical elements related to instructional text or narration have been found useful in reducing search on an instructional computer screen. This method frees added WM capacity for schema development.

The converse of the Law of the Focal Point is difficulty of comprehension when no clear focus is found on a given visual field. In the CLT context two key effects describe such a situation: the split-attention effect and the redundancy effect. In the first case there may be too many or too complex

items to focus on in disparate locations for the limited WM to cope with, and the suggested solution is to integrate the items in close proximity (Chandler & Sweller, 1992; Mayer & Moreno, 1998),i.e. focusing on a specific key aspect in the visual field in Gestalt terms. In the second case attentional resources are wasted on aspects not salient to the learning task in hand, and this hinders schema development. Here the solution is to make the focus of the critical attention clearer and eliminate irrelevant detail (Kalyuga, Chandler, Sweller, 1999; Chandler & Sweller, 1991).

The Law of Isomorphic Correspondence emphasizes the importance of the observer's prior schemas. The importance of the prior knowledge and schemas has been recognized in the CLT context for a considerable time (Tuovinen & Swller, 1999; Kalyuga, Chandler, Tuovinen & Sweller, 2001). That is, the schemas in LTM provide an important context into which new learned items will be connected. If relevant information is present, new material will be more easily integrated in to the existing knowledge network, or schema.

The Law of Prägnanz is another example where existing LTM schemas are used as the basis of organizing newly apprehended information as discussed above. Here the schemas are visual in nature, whereas many of the cognitive schemas considered in the CLT framework exist in semantic format.

A counterpart to the Law of Proximity in the CLT framework is the contiguous placement of learning materials (Moreno & Mayer, 1999). This is in effect a way of stating that the detrimental split-attention effects may be reduced or eliminated by the close placement of objects to be considered simultaneously.

The Law of Similarity suggests that similar shapes and sizes found among a clutter of other visual items may be identified as a single entity. Experiments in the CLT context with flashing indicate that attention can be focused on the relevant aspects of a complex visual field that need to be considered together for developing new schemas (Jeung, Chandler & Sweller, 1999).

The Law of Simplicity is another clear illustration of one of the basic principles of CLT, the need to reduce extraneous cognitive processing to allow the limited capacity of the WM to be fully devoted to productive schema development (Sweller, van Merrienboer & Paas, 1998). In this case it is sought to reduce the visual search in the visual field for the salient information by supplying it in the simplest format possible. Thus this approach overcomes problems such as the split-attention effect discussed earlier.

The Law of Unity relies on the existence of previously developed relevant schemas in the LTM which can then be utilized to reduce the processing in WM involved in the construction of the meaningful context for a set of visual elements. These schemas may consist of common geometrical shapes, aspects of the familiar human figure, etc. Thus when this type of well-known schema is utilized there is effort required in WM processing than if the schema had to be developed without a prior prototype.

4.2 Areas of no Gestalt and CLT theory overlap

The two Gestalt Laws identified in Table 1 that do not appear to have strong connections with currently identified principles CLT are the Law of Balance and Law of Figure-Ground. This is an interesting issue that could form the basis for further research and investigation.

5 INSTRUCTIONAL SCREEN DESIGN EXAMPLE: WOUNDCARE

The WoundCare multimedia program was developed over a number of years for nursing students, but very little effort had been expended on the program's user interface, and so an effort was made to revise the screen layouts. This allowed us to investigate the benefits and limitations of applying the merged 11 Gestalt laws and selected CLT principles to the visual screen design process. Five redesigned screens are presented in this paper (due to space limitations) and described in the following sections to explain how Gestalt theory has been incorporated with CLT to redesign user interfaces for an instructional application.

5.1 Screen redesign

As discussed previously, the Law of Balance/Symmetry states that psychological equilibrium is achieved by equalizing the visual weight of on screen components. On a computer screen, balance can be achieved by adjusting the items on the screen to equal visual weight. In figure 1, the animated graphics illustration acts as a visual pivot for the whole screen in order to achieve visual

balance. The left hand and right hand sides of the text button are balanced with respect to each other and the red WoundCare title is also balanced with the right bottom 'Help' and 'Exit' text/button elements.

Another example, illustrated in figure 2 shows that the title (Tutorials > Skin Anatomy and Physiology) balances the navigation tools on the bottom of the screen, and the tutorial learning text balances the review questions.

Another example, shown in figure 3, illustrates that the left-hand side index menu, the text in the middle and the three images on the right hand side integrate together to achieve closure. Note that the text and images are also grouped to achieve another closure effect. Here the text and graphics that were previously on totally different screens were integrated on a single screen to reduce a huge extraneous cognitive effort of keeping substantial quantities of new information in WM, while searching for complementary graphics or vice versa.

In every screen we used the 'Continuity' technique to persuade the learner's eye to perceive correctly the whole visual screen. In the revised screen design of the opening WoundCare screen in figure 1, the learner's eyes will follow the placement of the menu text around the entry point of central animation that shows the overview of the system, as it is a logical pathway for a learner's eyes to follow. As shown in figure 4, all the menu text has also been placed in logical order and this reinforces the effect.

In figure 3, the Continuity principle has also been used, as in the right hand side of the screen the learner's eye will be lead from the first image to the second and following on to the third image. On the left-hand side of the screen, the index menu has been designed in alphabetical order to assist the learner to follow through the menu. The continuity incorporated in these designs strongly suggests a pattern for the learner to follow, like in the worked examples practice mode in the CLT context. Thus the learner's search for salient information on these screens is reduced freeing more WM resources to be used in schema development.

The learner's focal point and attention in figure 3 is in the text area, but the focal point has changed to an image in figure 6. Another example is shown on figure 1, whereby the learner's attention will be caught by a first look at the center of the animation image. These are again guidance mechanisms analogous to CLT principles to reduce haphazard wanderings around a visual space, and thereby releasing WM resources to attend to the salient learning tasks.

Good Form been applied to the overall effect of the redesigned screens, e.g. see figures 1, 2, 3, 5 and 6, gives a sense of Good Form. In CLT terms existing LTM visual schemas are utilised to reduce unproductive search and unnecessary construction of new schemas.

The Law of Proximity can be seen in figure 3, each element is identified and is clearly placed in its place, e.g. navigation controls is placed on the bottom of the screen, index menu is placed on the left side of the screen. The space and round box creates a line to identify different groups, leading the student to directly link each group to its function. As noted previously, this approach reduces the detrimental split-attention effect by applying contiguity, or close placement of relevant learning elements (Mayer, 2001).

As well as using similarity to group similarly perceived items together, a reader's attention may be drawn to particular features of interest by breaking similarity, e.g. by borders, graphics/text boundaries, differences in shading, colour differences, highlights, underlining or dimmed key words. For example, in figure 2, 3, 5 and 6, a standard color and shape been used to group the navigation buttons together helps learners to learn and easily recognize the navigation buttons. Learners only need to use the navigation button once in the first session, and then they can go on to explore other sessions. Another example can be observed in figure 3 where the left index menu for the different InfoBase topics is contained within a single banded area, and the text and graphics on the screen are in different banded areas. These approaches achieve similar effects of grouping and distinguishing items as found in the use of flashing to distinguish relevant elements in the CLT context to reduce extraneous search..

Examples of simplicity of design are shown in figure 1, 2, 3, 5 and figure 6, where all the items are clearly displayed and available on the screen. Although there may be many items on the same screen for the learner to choose from, it still represents a much simpler or elegant way to group them together, which illustrates the principle of simplicity. As noted previously integration of learning elements in a single visual space reduces the split-attention effect in CLT terms.

The challenge of the Law of Unity in design is how to organize the related objects into the same form, and how to let learners combine the individual objects as a whole, when they are first perceived. Within each section of the program, we used the same type of transition to jump to the next page, in order to distinguish different section segments. On every screen we used the same text font, the left-hand side was always used for a sub-menu, each section title was always placed at the top right hand corner, and the negative button was placed consistently on the bottom of the screen. This consistency implements the unity law, and reduces

the cognitive load in dealing with a variety of formats.

6 EVALUATION

A pilot version of the redesigned WoundCare program was evaluated. The representative screens from each of the three main program sections had been redesigned, but the revised design was not applied to the all the screens in each program section. There were 12 participants in the evaluation, ranging from university students with previous experience with the original WoundCare program to academic staff and people who had not seen the program previously. Firstly, informal interviews and observations were conducted where the participants compared the two programs, then the participants completed a questionnaire.

6.1 Visual Screen Design Survey Results

The first five questions of the survey sought opinions about the quality of the redesigned visual interface. The results are shown in Table 3.

Overall, the evaluators rated the new interface design as more effective with better usability than the original version. In addition to the favorable survey ratings the student comments were also positive, e.g. "I found the program is very eye catching and user friendly." "This is an excellent version of the WoundCare program. It is easy to look at and to work through. As a study tool, it assists with the basics of WoundCare in an easy to follow fashion"

6.2 Analysis and discussion

In the redesign of the main WoundCare screens the Gestalt laws identified and the way the CLT principles were applied were found to be useful by an overwhelming number of respondents. Thus it appears that students and staff, most without special visual education, can recognise the value of the Gestalt laws and CLT principles incorporated in the in the visual interface design and to their own learning from multimedia designed using such principles.

7 CONCLUSION

This paper has explored a wider range of Gestalt laws than is often recommended for visual design of educational software. The eleven laws distilled from the Gestalt literature were related to the cognitive load theory and applied to the visual redesign of a multimedia educational program, WoundCare, in order to improve its appearance and educational effectiveness. The user evaluations indicate all the Gestalt laws and embodied CLT principles were beneficial for visual screen design and learning effectiveness. However, the comparative value of the Gestalt and CLT contributions to the visual redesign were not teased out thoroughly enough, so it will be useful to examine the relative benefits of these principles in greater detail in subsequent research, to arrive at better guidance for visual designers.

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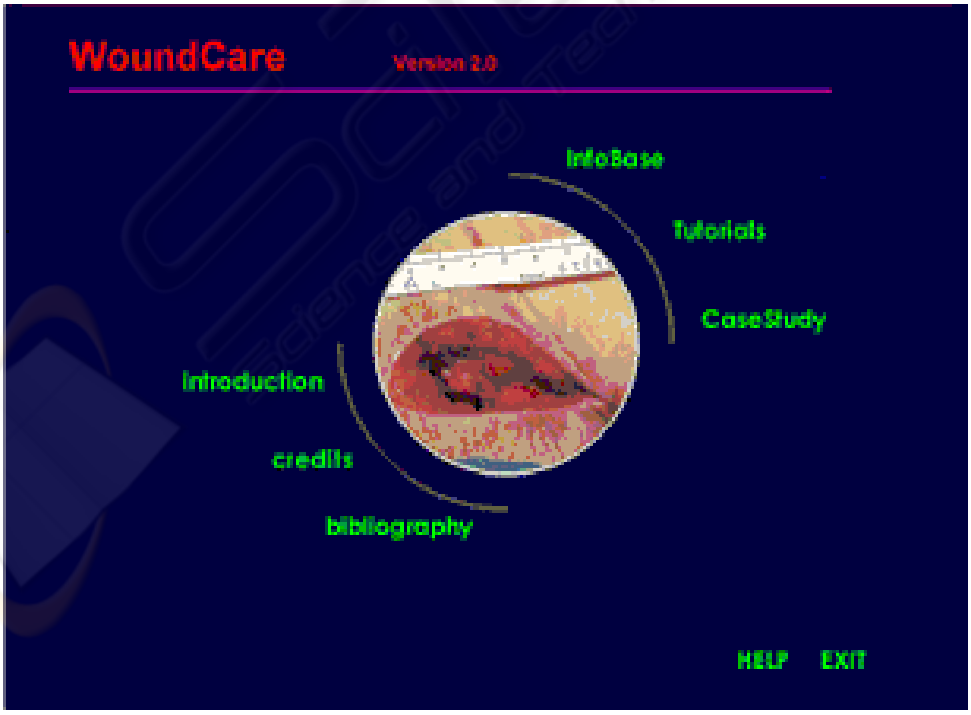

Figure 1: Revised screen design of the initial WoundCare.

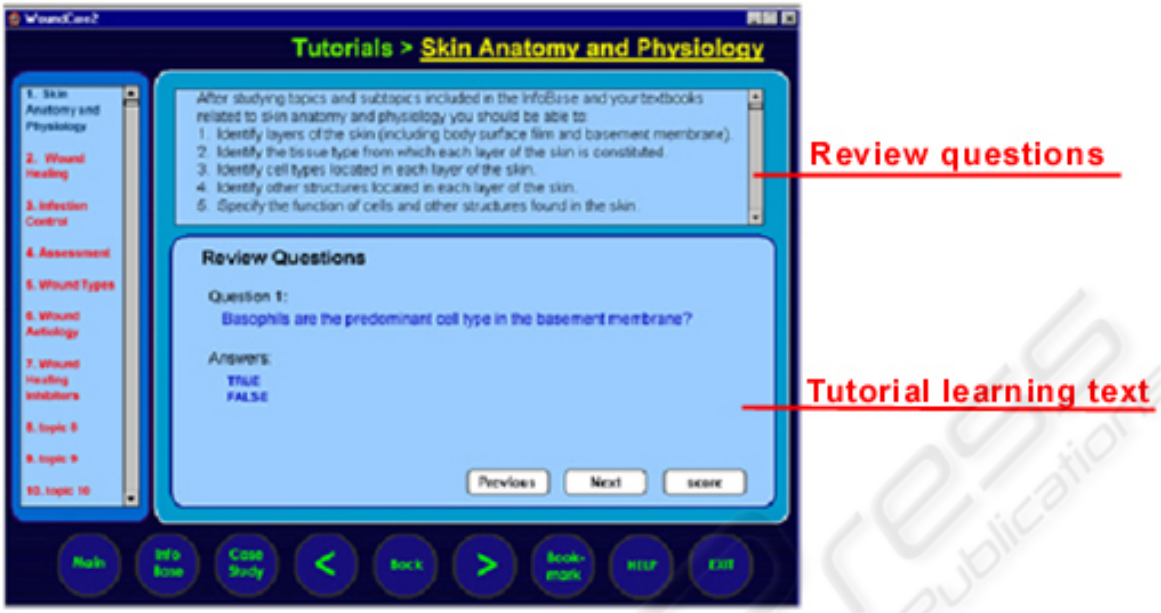

Figure 2: Redesigned Tutorials screen.

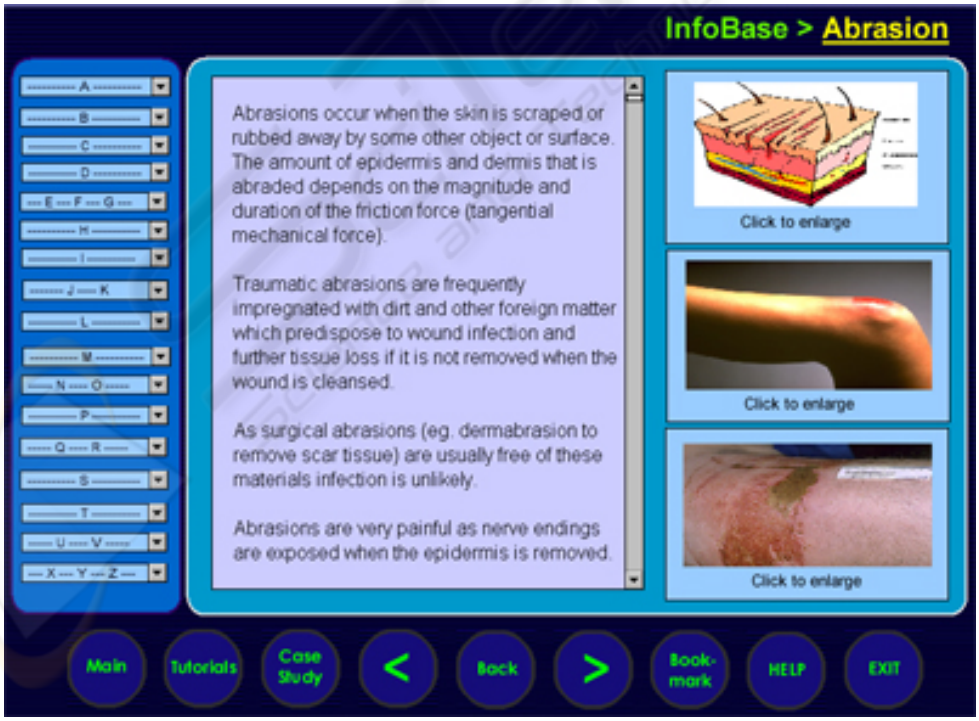

Figure 3: Integrated design of navigation controls, text and graphics.

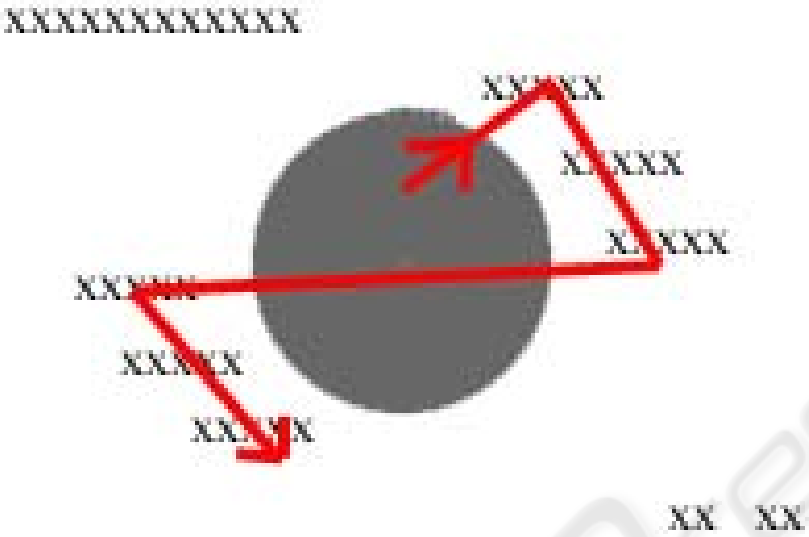

Figure 4: Logical order.

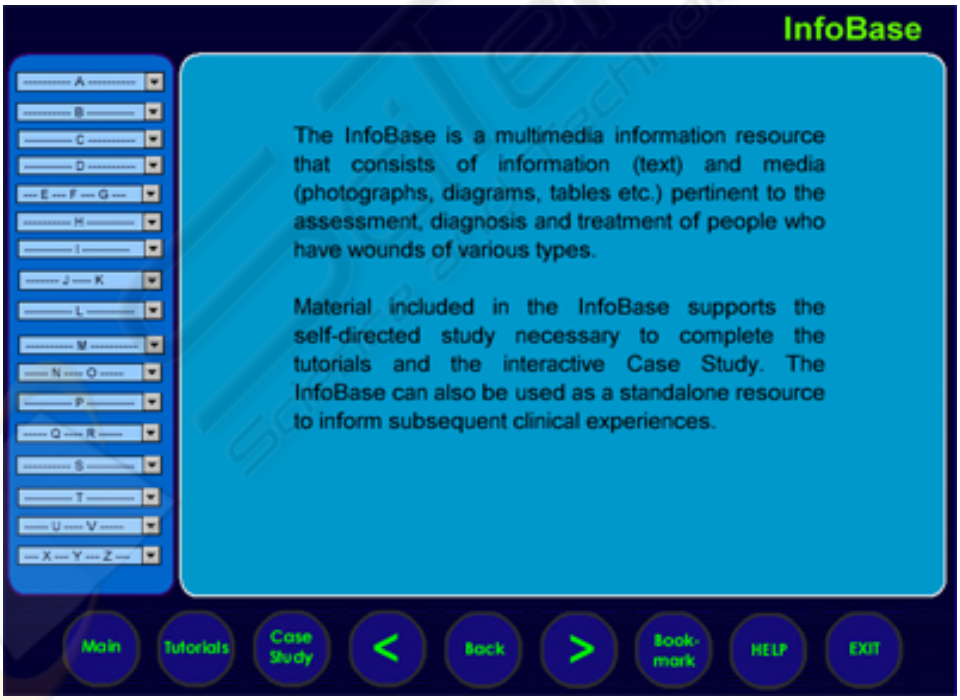

Figure 5: Redesigned InfoBase introduction screen with index menu.

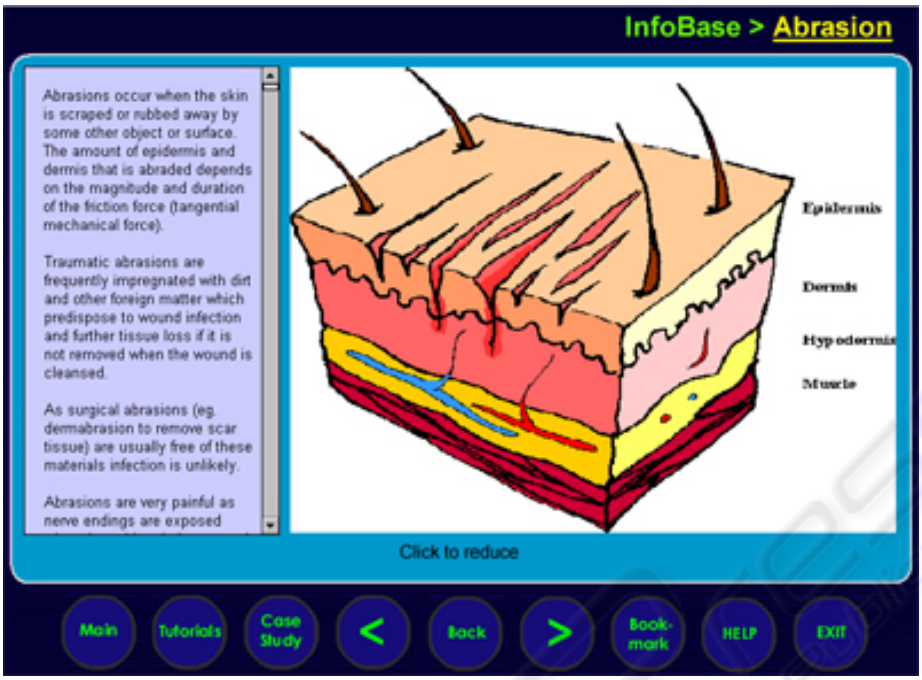

Figure 6: Redesigned integrated design, showing graphics in large scale with associated text and navigation controls.

Table 3:Questions and results about the quality of redesigned visual interface

Question (N= 12)	Yes	Undecided	No
Are the new interfaces better than previous WoundCare version 1.1?	100%	0	0
Was learning easier with new interface?	85%	15%	0
Is there enough detail instruction in the presentation to enable you to carry out the tasks/exercises?	100%	0	0
Was the navigation easy to follow?	100%	0	0
Are the links between the text and graphics/photographs/tables clear enough?	100%	0	0