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Model based Usability Heuristics for Constructivist e-Learning

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Abstract
Many e-learning applications and games have been studied to identify the common interaction models of constructivist learning namely- 1. Move the object to appropriate location 2. Place objects in appropriate order and location(s) 3. Click to identify 4. Change the variable factors to observe the effects 5. System personification and dialogue with learner. The paper also presents around 14 qualitative aspects, which can serve as heuristics for evaluation of constructivist e-learning. The common interaction models and qualitative aspects are defined to help in improving the effectiveness and usability of constructivist e-learning.

Keywords
Constructivist e-learning, *Common Interaction Models*, Usability Heuristics

1. Introduction
In real world scenario, the learner constructs knowledge through physical interaction, sensory experience and cognitive process. This interaction is direct and it happens at physical, sensory and psychological levels of the learner. The real world response to this interaction is real and governed by the lows of nature. But learner's construction of hypothesis and knowledge formation is often subjected to perception and interpretation of experience. The real world can be considered as the objective and authentic source of learning. Gaps or the errors in one's understanding of the real world can be attributed to one's limited capacity to analyze and comprehend. Such theoretical basis for constructivist learning has been provided by J. Bruner (1960, 1966) in his profound work on the process of education and the theory of instruction[1].

[1] A major theme in the theoretical framework of Bruner is that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge. The learner selects and transforms information, constructs hypothesis, and makes decisions, relying on a cognitive structure to do so.

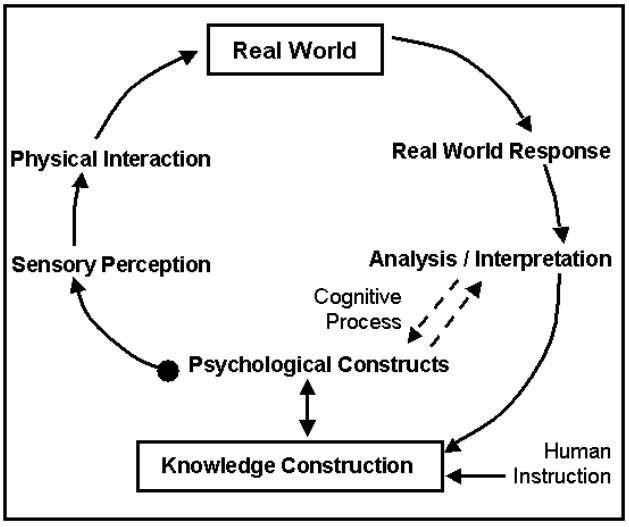

Figure 1. Knowledge construction in real world

It is necessary to compare the process of knowledge construction with real world and simulated world. See figure 1 and 2.

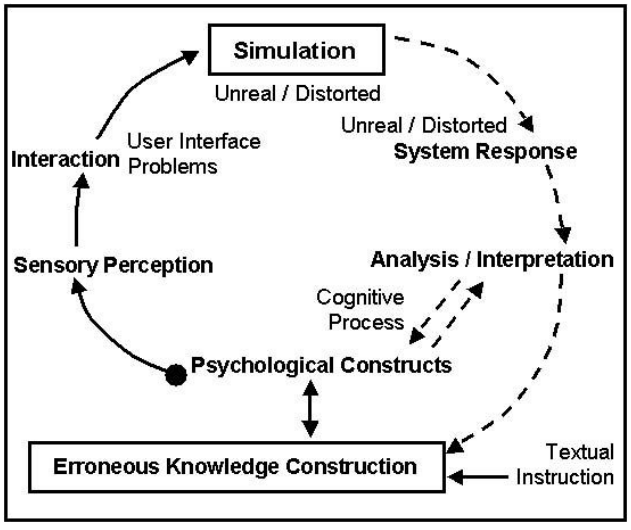

Figure 2. Knowledge construction through simulation

Computers are increasingly used to design interactive games and educational experiments for promoting constructivism through e-learning. This has become possible due to advancements in interactive multimedia, 3D/2D animation, virtual reality, artificial intelligence and interaction devices like mouse pointer, keyboard, touch sensitive screen, sensor gloves, joystick, etc. Computer based simulations lack in detail and natural behavior if compared with the real world. The medium itself introduces several distortions due to constraints. This can affect the quality of constructivist e-learning.

In this context, we propose to confirm our hypothesis through study of various constructivist e-learning applications. Our hypothesis involves two arguments-

a. **Constructivism in e-learning applications follows certain patterns of interaction**

We propose to identify the *common interaction models* so that e-learning developers can use them with greater clarity and precision. ***Common interaction model*** **means 'the basic scheme of user input and system response in the user interface paradigm'.**

b. **The technical constraints and design problems can cause erroneous knowledge construction**

We propose to identify the qualitative aspects related with the *common interaction models* to improve the usability and effectiveness of constructivist e-learning. This effort will be helpful in articulation of usability heuristics for the formative evaluation of quality.

2. Methodology

We have observed many web based interactive learning applications, educational games and simulations of scientific experiments to identify the *common interaction models*. Specific case studies are carried out to identify the qualitative aspects (both positive and negative) of constructivism in e-learning. In some cases appropriate subjects are involved for feedback.

3. Common Interaction Models (CIM)

CIM-01. Move the object to appropriate location

The Woodlands Junior School website provides various literacy games for children. It provides a simple game called 'Can you place a full stop in a sentence' (see figure 3). This game is set up on the backdrop of a ship. There are red balloons hanging on both sides which when used in sentences turn into full stops. After clicking the ropes, sentences are presented before you. Then you have to drag a red balloon and place it in the sentence. If placed at the end of sentence it becomes a full stop or it returns to its original location. The captain rewards you by offering chocolates if the full stop is properly placed.

Description of CIM-01

In this interaction model, one has to move an object to correct location or it returns to original place. Usually, one uses mouse to pick the object and drags it to the desired place. There can be a real object and a real situation or one can weave an imaginary situation around the main activity. In the first case, there are fewer problems with regard to learning.

Figure 3. Can you put a full stop in a sentence

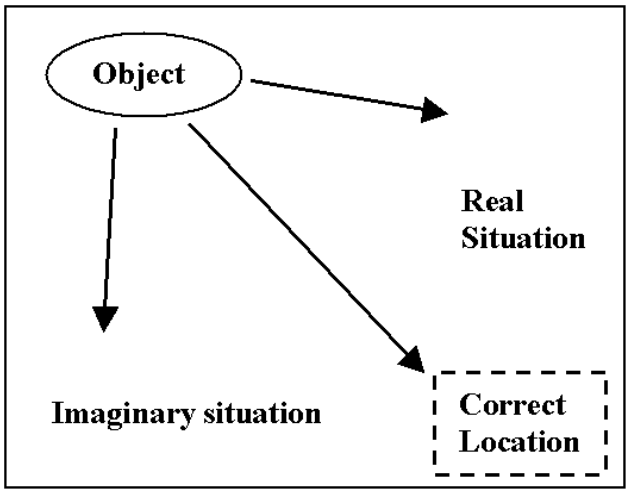

Figure 4. CIM-01 Move the object to appropriate location

Qualitative Aspects

- **Separate the imaginary situation and the learning objective**

Ship, ropes and balloons are part of imaginary situation and have nothing to do with the grammar. It is quite possible that children might construct wrong hypothesis e.g., one may believe that full stops are basically the red balloons hanging on a ship. Also the reward of chocolates

offered by the captain is fictitious. The imaginary situation is not the objective of learning but it is meant to make learning playful. The application should ensure that finally children understand pure grammatical rules. Initially the learning objective can be **implied** in the activities but it must become **explicit** towards the end of game.

- **Use real world situations with clear learning objective**

It is ideal to model real world situations with clear learning objective as it helps the learner in building correct hypothesis.

- **Use combination of imaginary and real world situations**

Imaginary situations make learning playful and memorable whereas real-world situations make it more concrete and precise. Imaginary situations are helpful in illustrating abstract concepts or ideas e.g., grammar. They can serve as metaphors or analogies. Therefore, both imaginary as well as real situations should be used appropriately.

- **Avoid obvious pattern of interaction (cover many possibilities)**

In this game, only single sentences are presented. Obviously, after initial two/three trials, you figure out that the full stops have to be placed towards the end of sentences. Naturally, thereafter, you start placing full stops without reading the sentences and yet complete the game successfully. It will be ideal to have multiple sentences without punctuation, which will force children to read the text, to identify correct locations for inserting the full stops. It will help them in understanding the grammatical structure of sentence, which is the main objective of learning.

- **Offer reward as well as punishment**

The captain of the ship offers chocolates if you do it right but there are no punishments for wrongdoing or for leaving the lesson incomplete. Reward and punishment both are necessary to motivate the learners.

CIM-02 Place objects in appropriate order and location(s)

Engineering Interact website of University of Cambridge provides very interesting learning material. We have selected two examples from this website to illustrate this interaction model. In the first example (see figure 5), an object has to be moved against light to know about its shadow properties. The experiment teaches you that opaque objects cast shadows, and transparent objects don't cast shadows. This is an example of moving different objects to certain location and observing the results.

In another variation of this interaction model, one has to build an electrical circuit by arranging appropriate components such as bulb, switch, battery, connectors, etc. The bulb lights up only when the circuit is properly fixed.

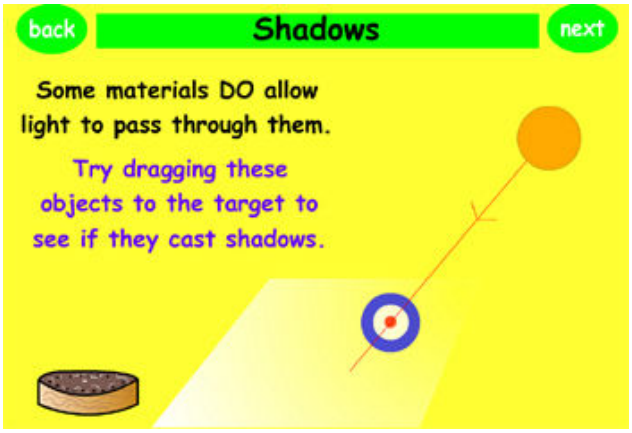

Figure 5. Learn about shadow properties

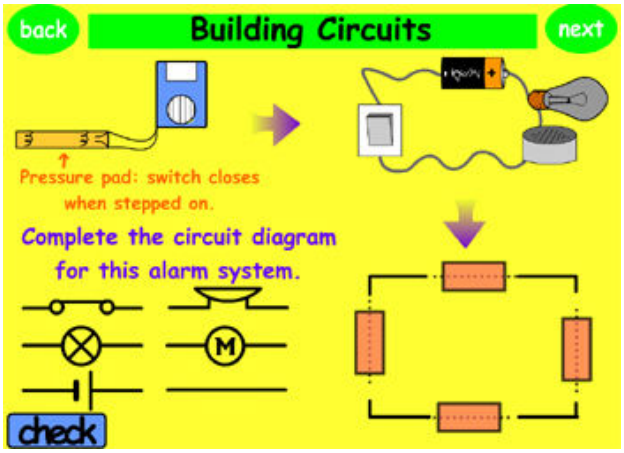

Figure 6. Build proper circuit

Description of CIM-02

In this interaction model, one has to shift many objects to certain location(s) with logical order.

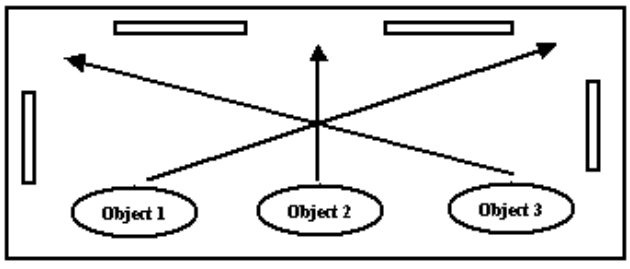

Figure 7. CIM-02 Place object(s) in appropriate order and location(s)

Qualitative Aspects

- **Indicate object affordances**[2]

In both examples, it is not easy to recognize the objects that can be moved. The intended locations of objects can be made more visible or one may allow the learner to discover them through trial and error. Visual indications like cursor change on mouse over or blinking outlines can be used.

- **Explain the reasons of acceptance or rejection**

The game of shadow properties (see figure 5.) provides reasons of why an object casts or does not cast shadow. But the circuit game (see figure 6.) does not inform you about why a circuit failed. Also in many multiple choice tests, one ends up selecting correct option accidentally without knowing the background information.

- **Map the diagrams with reality**

If you see the screen shots in figure 5 and 6, the sun or the ray of light or the rectangular circuit are too diagrammatic and not recognizable. Therefore, it is necessary to make these diagrams visually illustrative or map them with reality to make it more recognizable.

CIM-03 Click to identify

Miami Museum of Science website provides interesting lessons meant for constructivist learning. We are discussing the lesson that introduces you to various parts of tongue that feel different tastes. The lesson shows a picture of lemon and asks you to click on various parts on the picture of tongue to find the places where sour taste is sensed. On clicking it correctly, that part of the tongue is indicated by green color as shown in figure 8.

Figure 8. Identify where sour taste is sensed by tongue

Description of CIM-03

In this interaction model, one has to identify the missing elements or recognize something in the given image or scenario.

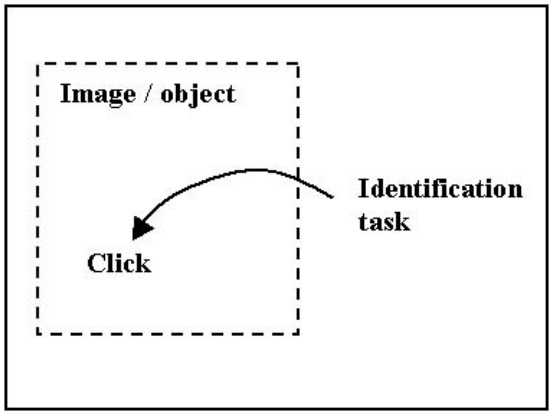

Figure 9. CIM-03 Click to identify

Qualitative Aspects

- **Undistorted indication of correct identification**

As shown in figure 8, the color of tongue changes to green, to indicate the area where sour taste is sensed. The learner can take the green color of tongue literally and construct distorted knowledge about the tongue. Such distortion must be avoided.

CIM-04 Change the variable factors to observe the effects

National Taiwan Normal University website provides various lessons which can be explored to learn physics fundamentals. We are discussing the experiment that teaches you about how the shape of a thing you see under the water surface is different from what it really is. The interactive application shows an underwater fish, a rectangular object and its perception from fish's point of view as shown in figure 10.

Description of CIM-04

It is about understanding the interrelationships between the elements by modifying them and the underlying reasons by observing the results.

Qualitative Aspects

- **Clearly indicate the variable factors**

One has to explore a lot to find the variable factors in the physics experiment shown in figure 10 e.g., the eyes of fish can be moved aside.

- **Reveal the reasons of change**

The connecting lines between the eyes of fish, the object and its perceived image show the interrelationships and

[2] Perceived and actual properties of the thing (Donald Norman, 1988).

the effect of change. But the reasoning is explained through elaborate text.

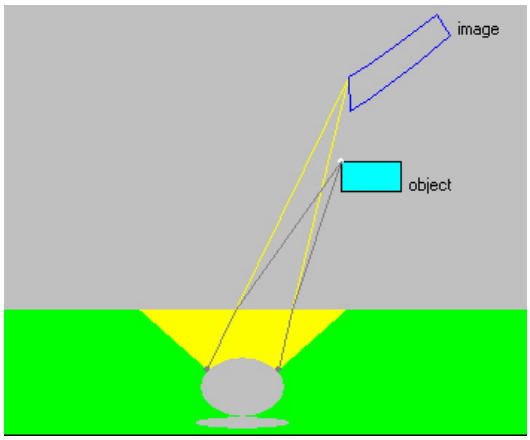

Figure 10. View from underwater

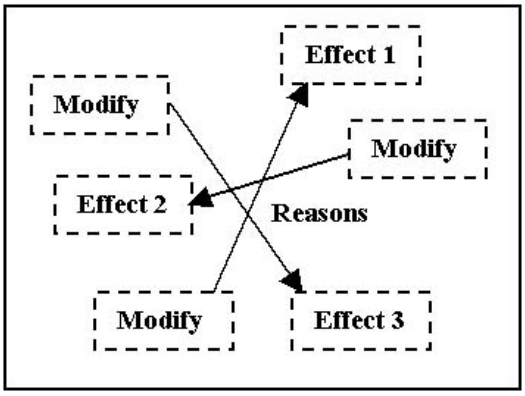

Figure 11. CIM-04 Change the variable factors and observe the effects

CIM-05 System personification and dialogue with learner

The teams of C-DAC, Pune and Mumbai along with Watershed Organization Trust (WOTR), Ahmednagar are jointly developing a computer game for teaching watershed management techniques to villagers. The game provides theoretical knowledge of various treatments in the beginning. It helps the players in selection and application of watershed treatments on the simulated terrain. **A wise villager (virtual guide) asks series of questions to players to make them realize the need of watershed management (see figure 12).** Basically, it helps in realizing the context. The players can input their reply by selecting an option provided on screen. Based on the reply of players, the wise villager reacts wittily. He speaks in the dialect familiar to villagers.

Learning Management Systems (LMS) often encourage online chatting between instructor and learner. But chat is synchronous and the example shown in figure 12 is more like multiple-choice questions. But the question is presented by the wise villager in speech format.

Figure 12. The wiser villager conversing with the players

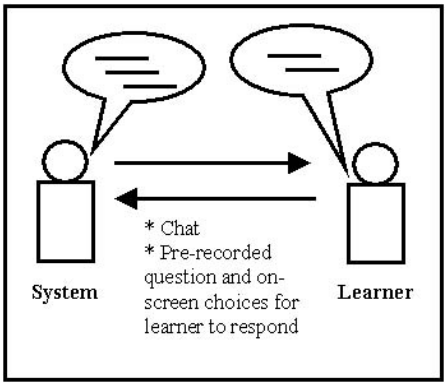

Figure 13. Interaction model of ' system personification and dialogue with learner'

Description of CIM-05

Personification of learning system (in the form of teacher, guide or mentor) helps in winning the attention and involvement of learner. An emotional bond can be developed through conversation between teacher and learner.

Qualitative Aspects

- **Give personal attention to learner**

Seeing and feeling the presence of teacher is the psychological requirement of learners (Katre, 2005). It makes learners more attentive, receptive and accountable towards learning objective.

- **Help learners realize the context**

Learning is always context dependent; it is more so in constructivist approach. Things can be misinterpreted if the context is unknown.

- **Speak learner's language**

Speaking learner's language is most crucial for achieving acceptance and effective learning. It is similar to the usability heuristic 'speak users language' by Neilson and Molich (1990).

4. Conclusion

Following *common interaction models* of constructivist e-learning are identified.

CIM-01. Move the object to appropriate location
CIM-02. Place objects in appropriate order and location(s)
CIM-03. Click to identify
CIM-04. Change the variable factors to observe the effects
CIM-05. System personification and dialogue with learner

It seems like a plausible idea to identify *common interaction models* of constructivist e-learning. It will be possible to properly articulate and fine-tune them for greater accuracy of constructivist e-learning.

Following usability heuristics for evaluation of constructivist e-learning are identified.

- **Give personal attention to learner**
- **Speak learner's language**
- **Help learners realize the context**
- **Separate the imaginary situation and the learning objective OR**
- **Use real world situations with clear learning objective OR**
- **Use combination of imaginary and real world situations**
- **Avoid obvious pattern of interaction (cover many possibilities)**
- **Indicate object affordances**
- **Explain the reasons of acceptance or rejection**
- **Map diagrams with reality**
- **Undistorted indication of correct identification**
- **Clearly indicate the variable factors**
- **Reveal the reasons of change**
- **Offer reward as well as punishment**

It is definitely not a finite set of common interaction models and usability heuristics for constructivist e-learning. It is possible to identify more of them. But we hope that the outcome of this study will be helpful in providing some basis for qualitative evaluation of constructivist e-learning. It is also true that all usability heuristics will not be applicable in every situation. The usability expert will have to choose the suitable heuristics depending on the type of interaction model and the application.

5. Future Work

We would like to study more examples of constructivist e-learning and identify the remaining interaction models. It is necessary to make the usability heuristics more comprehensive. Finally, we propose to test the heuristics and evolve quality metrics for evaluation of constructivist e-learning.

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