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Considerations for human–computer interaction: user interface design variables and visual learning in IDT

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Abstract

The purpose of this study is to discuss approaches for developing human–computer interaction (HCI) in educational technology (ET) based on definitions of visual design, learning variables and user-interface design principles in the field of instructional design and technology (IDT). We will do in several stages, first, we will review historical definitions of HCI and its developments in education and considerations for defining visual literacy for learning with instructional design (ID) models. Then, we will review each definition of visual principles for user interface design (UID) or user experience design (UED) and learning from screens. HCI and its roles with the perceptional approach will be discussed as previous definitions in the type of theories such as cognitive load, activity and paying particular attention to primary concepts included in each definition based on the ID model approach. We will also present some of the historical criticisms of the definitions, which provided designing and developing user interfaces. The process should indicate or address possible performance design approaches in ID steps for developing learning and teaching in learning environments as well as developing UID or UED in ET. This also indicates approaches in philosophy of ET and its theory, definition and applications of new technologies as well as UID or UED perspectives and visual design variables. In this study, we review the visual design techniques from past to present that multimedia project design teams should follow the strategies and rules for designing learning environments in industry, business and military based on philosophy of ET and HCI design with ID models by using the newest technologies. The process compares both understanding global UID or UED requirements and visual strategies and considerations for research and product design by ID models. The steps include recognising terminology in ET practice concept, psychological, technological and pedagogical foundations in ID as well as ET approaches and using visual rules for conducting multimedia projects in last decays. At the end of the study, conceptions of ET, ID models and HCI will be discussing to indicate design standards for multimedia projects in the field of IDT. We will also present the relationships between ET and designing problems for creating instructional materials in education. All steps in visual design, UID, UED and HCI design based on philosophical approaches and evaluations in the field are given at the end of the study.

Keywords: User interface design, visual designs, human–computer interaction (HCI), user experience design, educational technology, IDT.

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1. Introduction

Human–computer interaction (HCI) can be defined as the discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and the study of phenomena surrounding them. In general, HCI deals with the study of people, computer technology and techniques, which influence each other (Ipek, 1995). It can also be defined as an area of research that seeks to understand the interaction between technology and the people who use it (Earnshaw, Tawfik & Schmidt, 2018; Rogers, 2012). HCI indicates interaction from many perspectives, two of which are usability and user and user experience (UX). Usability defines how easily the interface is able to be used as intended by the user (Nielsen, 2012). The purpose of the computer–human interface (CHI) studies is to determine how CHI specialists can make this technology more useable by people (Dix, Finlay, Abowd & Beale, 1993; Henderson & Card, 1986; Ipek, 1995). CHI involves researchers from psychology, computer science, information science, learning design, engineering, instruction and communications. The main concern of HCI is to define the effects of human physical, cognitive and affective characteristics on the interactions between users and devices for specific tasks. For this, HCI researchers must design instructional structures of human activity and use these structures in designing new interfaces in visuals. The human–computer interface is a communication channel between the user and the machine. The interface contains both physical and conceptual components in technology education (Ipek, 1995; 2010; 2011; Marchionini, 1991).

2. Theoretical foundations

2.1. Cognitive load theory (CLT)

CLT indicates that learning is gained on effective cognitive processing without having misunderstanding; however, learners have a limited capacity for this information processing (Ipek, 2001; Mayer & Moreno, 2003; Paas & Ayres, 2014). The theory includes intrinsic load, germane load and extraneous load (Sweller, van Merrienboer & Paas, 1998). Intrinsic load shows the active processing or presents verbal and visual learning activities in working memory, also known as short-time memory (STM). Extraneous load includes some factors, but they are not effective or essentials for learning in class but they are still there for learning (Korbach, Brnken & Park, 2016). Germane cognitive load describes the relevant process used by the effective and high-quality instructional design (ID) for learning materials. The load is based on creating schemas in long term memory. It is very important to clarify that elements of CLT are countable based on learning, if learning is to appear, the total load cannot exceed STM.

Extraneous load process is of special importance for HCI and usability. The process can be changed by the designer. In the same way, poor navigation structure causes unexpected results for learners to find any button and click quickly to reach necessary information. If learners are unfamiliar terminology in interface design, they would not deal with mental models for understanding the interface.

2.2. Distributed cognition and activity theory

There are effective theories and models for using their impact on HCI while CLT helps explain the individual interactor of a UX. The distributed cognition and activity theory has broader context of learning and explains teamwork as collaboration between team members. The theory proposes that learning is present both within the mind of an individual or team members and across artefacts (Hollan, Hutchins & Kirsh, 2000).

Activity theory follows a similar way to distributed cognition but focuses on the activity and roles within and interconnected system and learning process. It follows teamwork and group behaviours based on a goal-oriented hierarchy that includes activities, actions and operations (Jonassen & Rohrer-Mrphy, 1999). Activities include objectives and motivational needs. In learning, these are often

technology applications that subgroups must complete. For instance, the learning management system or new designed training program will be an example of this process. Actions are specific and goal-directed works. The activity theory provides useful design strategies to understand how objectives are gained in learning context.

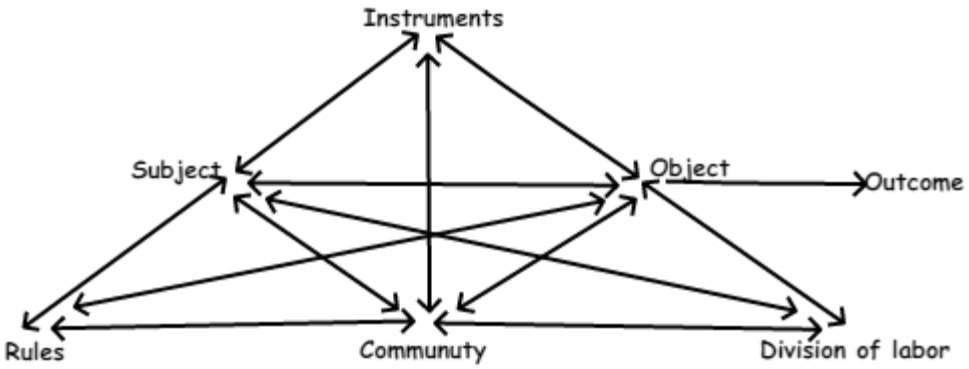

Figure 1. Activity system diagram (taken from Earnshaw et al., 2018)

3. HCI and interface designs

Treu (1992) indicated that the interface structure in HCI includes conceptual, logical and physical patterns. The user and machine relationship is based on knowledge structure. There is a direct visual and language-based interaction between user and computer. The interaction is based on conceptual and logical structure-based correspondence. Basic interface structure is presented with a structural symbol, cognition and memory and computer-based representation. Structures in knowledge are presented by the user-model that a symbol in the structure indicates the effects of human cognition and memory. For instance, symbol (W) stands for a window that indicates regions, spatial objects, visual and imaged objects, location, distance and spatial organisation in cognition and memory processing (Ipek, 1995). For his reason, user interface design (UID) and user experience design (UED) deal with learning strategies, visuals and learning theories to have user-centred design (UCD) in HCI. It also indicates how to use these roles in learning and instructional design and technology (IDT). The principles of HCI and using design variables have applications for the design of learning such as visual literacy, interface design and technological characteristics in educational technology (ET) (Guney, 2019a; 2019b).

4. User-centred design (UCD)

UCD is indicated with a specific focus on methods for developing UCD into instruction design steps and stages. These stages are analysing user-needs, data gathering, creating prototype and wireframing (Earnshaw et al., 2018).

5. Analysing user needs and problem analysis

This part of the ID model is considered as a need assessment and problem analysis based on the ADDIE model as well as Seels and Glasgow model (1998). At this time, user-needs can be analysed as a first step in the project development by using ID models. UCD processes also begin by analysing user needs. While developing ID projects, designers should be aware of ID models and their trends in the educational process. Coffey (2017) indicated that ID trends in nowadays include the following trends. They are:

- Personalisation in ID.
- Providing contributions with training and communication for learning and cultural differences and changes.
- Consistent time with organisations and the cultural perspectives of learners for rapid delivery of instruction.
- Combination of e-learning and integrated e-learning with instructor and social learning activities.
- Technology literacy and newish technologies will be in future IDT for designers, teachers, developers and learners.

Requirements gathering from the UCD approach help avoid application of a ready-made solution in favour of creating ID procedures that meet all objectives and collecting data for learner needs. ID models also present all valuable audio-visual design considerations and requirements in user-interface design.

6. Designing and developing user interfaces

Basically, UID includes several components such as visual characteristics, technical features and instructional characteristics for designing materials to gain user interface features in instruction.

6.1. Rapid prototyping

Rapid prototyping is an approach to design that used in the 1980s in engineering fields and started to use in the field of ID in the early 1990s (Desrosier, 2011; Gentry, 1994; Seels & Glasgow, 1998; Tripp & Bichelmeyer, 1990; Wilson, Jonassen & Cole, 1993). Prototyping is also defined as the process of assembling, pilot testing, respecifying, validating and finalising an instructional unit (Gentry, 1994). Seels and Glasgow (1998) indicated that prototype development takes place during the design phase of the instructional systems design process. The process starts with analysing data and includes objectives and assessments, instructional strategy, delivery system approach, preliminary design document, prototype development and final design document and development phase as well. There are two reasons for developing a prototype. First, the designer may have questions about students' ability to learn from and use the new system. Second, when a new technology is involved, there may be a question about the design team's performance and new ways of doing this (Seels & Glasghow, 1998). On the other hand, Gentry (1994) indicated that the prototyping process has the following steps:

- Receive the prototype elements from the production and design team.
- Check elements received against the design features and reconcile discrepancies in design teams.
- Design the interfaces for assembling the prototype elements.
- Complete evaluation steps for prototype development.
- Analyse formative evaluation data and report any instructional recommendations to design materials, contents and lessons.
- Sequence and integrate the revised design elements provided by the ID and production team for repeating some steps.
- Generate specification for marketing and send them to design and production units.
- Summatively evaluate prototype and
- Submit finished product master and final design.

According to Northrup (1995), prototype may emphasise the general flow, screen design, button placement, use of a metaphor, font, learner control, interactivity, user interface and multiple media, including visual design elements, animation and video effects as well as storyboards. As a result, interactive strategies and cost effective for developing a prototype are evaluated. There are several criteria to evaluate user-friendliness of interactive strategies, including accessibility for users, responsiveness, flexibility and memory for examining decisions and performances as well.

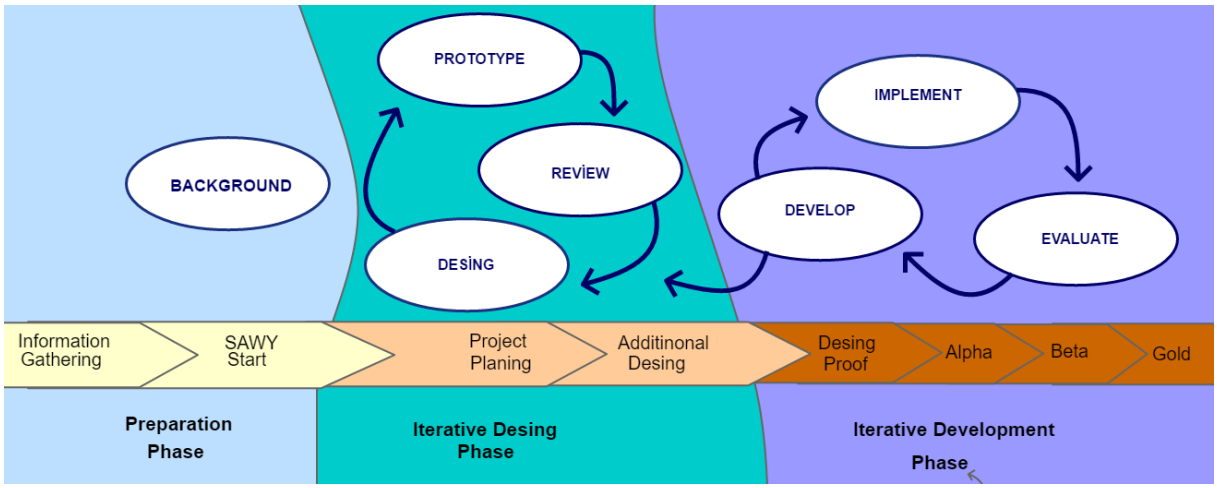

Figure 2. Successive approximation model 2 (SAM2) (taken from Earnshaw et al., 2018)

6.2. Paper prototyping

The focus of paper prototyping is not on layout or content but on navigation, workflow, content and functionality in the visual design process. Using pencil and paper is an easy approach to create paper prototyping, but coloured markers and coloured paper can also be used for designing visuals based on visual literacy effects (Fig. 3). The speed of paper prototyping makes easy scanning for using digital tools (Earnshaw et al., 2018; Snyder, 2003; Usability Net, 2012).

Figure 3. An example of paper prototyping

6.3. Wireframes

They are a representation of interface design that visually conveys their information process on screens. For this, visual design and layout design principles should be used effectively and efficiently on windows (Ipek, 1995; 2001; 2010; 2011). It also provides higher fidelity and functionally for using screens and developing materials as well. Wireframes consist of simple representation of an interface with interface elements displayed as visual symbols in screens. As an example of a wireframe, a web page is given in Figure 4.

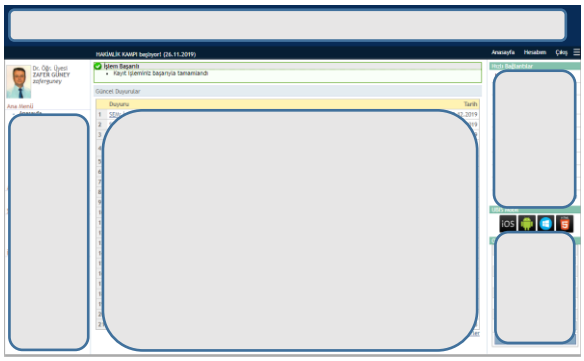

Figure 4. Example of a wireframe

6.4. Functional prototyping

Functional prototypes provide a powerful technique to generate feedback and corrections from users in the future stages of the design to refinements on development. A visual design is developed and added to the wireframe. In this process, an advanced functional prototype might look like a real interface with a lack of full features and can be created using software like InVision and UXPin (Earnshaw et al, 2018).

Designers in instruction also use tools in conjunction with evaluation techniques to better align interface designs with users mental structures for reducing cognitive load and increasing usability. UX design is often used interchangeably with terms such as UID and Usability. However, Usability and UID are important aspects of UX Design, they are subsets of it. UX design includes a vast array of other different areas, too. UX designer considers the why, what and how to product use in interface design process. Thus, each stage (Why) deals with motivations and values, the second stage (what) deals with functionality features and the last stage (how) considers accessibility and aesthetics as given in Figure 5. For this, the UCD process is evaluated based on method, design and data sources. UCD is an iterative process that takes an understanding of the users and their context as a starting point for all design and development. The process is given in Figure 6.

Figure 5. UX design and queries (taken from The Interaction Design Foundation, 2019)

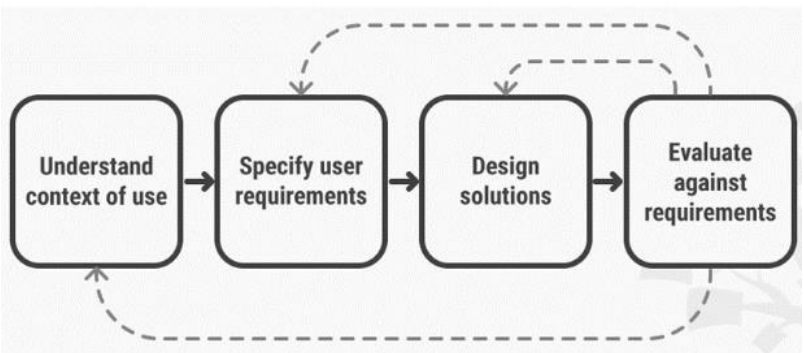

Figure 6. UCD (taken from The Interaction Design Foundation, 2019)

7. Visual design and visualisation for user-interface design

Wong (2019) indicated that user-interface design principles for HCI are based on several design factors that can be called as consistency, using shortcuts, providing informative feedback, designing conversations to yield closure, offering simple error handling, permitting easy reversal of actions, providing internal locus of control and reducing STM load. They can also be named as Shneiderman's eight golden rules for better interface design. At this time, visual representation in HCI should include typography of text, maps and graphs, schematics drawings, pictures, information and link diagrams, icons and symbols, visual metaphor and unified theories of visual representation, including screen design and examples of graphical user interfaces as well (Fig. 7). Thus, UID and UED can be used interchangeably to present design stages that include interactive design, information architecture, visual design, functionality, usability, typography, user interface and content strategy steps. Basically, UED includes visual design, interaction design, information architecture, development, technology and media parts, these functions have a connection with the experience, the user and context for HCI design in education (Figs. 7 and 8).

Figure 7. UID variables and visual learning in IDT (adapted from The Interaction Design Foundation, 2019)

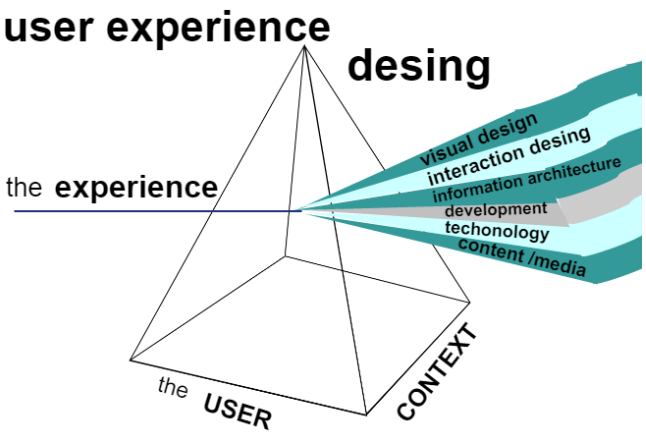

Figure 8. Tree dimensions of UX design and its variables (adapted from The Interaction Design Foundation, 2019)

In general, each UED should be useful, usable, findable, credible, desirable, accessible and valuable characteristics for designers, users and educators in the audio-visual design classes (Blackwell, 2019; Tractinsky, 2016). The characteristics are given in Figure 9. In addition, visual aesthetics in the field of

HCI is an important design variable from various perspectives. There are three perspectives, including the design perspective, the psychological perspective and the practical perspective. Although these perspectives are not meant to be exhaustive, they conclude all arguments for the inclusion of visual aesthetics as a major aspect of HCI practice, research and education in visualisation and visual design (Guney, 2019a; 2019b; Tractinsky & Hassenzahl, 2005).

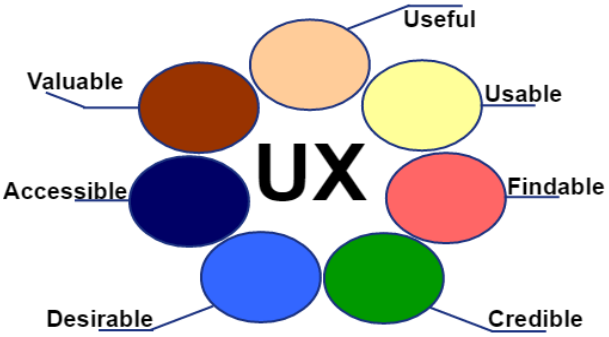

Figure 9. Seven factors that influence UX (adapted from Morville, 2004)

8. Evaluation methods and UCD

HCI and UCD principles are important design variables in ID models for learning and teaching. Thus, several evaluation methodologies for UCD are described to develop visuals by using technology in learning environments. These can be applied in design and data sources as part of ID models (Earnshaw et al., 2018). The evaluation steps are given in Table 1.

Table 1. The evaluation methodologies, design phases and data sources (taken from Earnshaw et al., 2018)

Method	Design phase				Data source
	Front-end analysis	Prototyping			
		Paper	Wireframe	Functional	
Ethnography	•				Single user or users
Focus groups	•	•			Group of users
Card sorting	•	•			Single user, multiple users or group of users
Cognitive walkthrough		•	•	•	Expert
Heuristic evaluation		•	•	•	Experts
A/B testing		•	•	•	Multiple users
Think-aloud				•	Multiple users
EEG/ Eyetracking				•	Multiple users
Analytics				•	Multiple users

- **Ethnography**. It is a method in research design that is used in the front-end analysis, especially for gathering information. It is also a qualitative research method in native setting for UCD with learning technology.
- **Focus groups**. They are often used during the front-end analysis in ID and as an evaluation method indicate discussions with a small group of participants about concepts and products.
- **Card sorting**. Positioning designs with users, mental models are important for effective user-experience (UX) design. Card sorting is usually used in psychology and education to identify how people set up, design and categorise information (Hudson, 2012).
- **Cognitive walkthrough (CW).** CW can be used during all prototyping stages. CW is a hand inspection technique in which an evaluator, not a user evaluates interface in realistic tasks. The technique is not a user test based on data from users but instead is based on the evaluator's decisions.
- **Heuristic evaluation.** Heuristic evaluation is a review technique that does not include directly working with the user. There are several heuristic lists that are used in heuristic testing. In the field of ID, Nielsen (1994) defined usability steps for problems in heuristic evaluation that can also applicable to evaluation of e-learning systems (Mehlenbacher et al., 2005).
- **A/B testing.** The method is known as split-testing to compare two versions of a user interface and prototyping steps. All versions are tested at the same time. Screen design elements, general text layout and navigation structure are evaluated to create effective UCD.
- **Think-aloud user study.** It is only used during the functional prototyping stage that will be used effectively as a single most valuable usability technical method (Nielsen, 1993). This method cannot be natural for users, so it is critical for designers to encourage users during the study (Earnshaw et al., 2018).
- **EEG/Eye tracking.** EEG measures a participant's brain activity while viewing visuals and records changes in the brain's electrical signals in real time. At this time, learner behaviours and eye movements with the user interface can be shown based on learner or user perceptions with screens and visuals.
- **Analytics.** It is an evaluation method that focuses on participant's behaviour is analytics, which is especially gathered in the background while a user is interfacing with systems and visuals without aware of the data collection. The method can be effectively used with problem-based, case learning and instructional gaming in multimedia design projects.

9. Conclusions

All steps in visual design, UID, UED and HCI design based on philosophical approaches and their evaluations should include processes for UCD. They include several parts for this process, including contents, user requirements, design solutions and evaluating against requirements as given in Figure 6. HCI should include user-interface design steps, and visuals design principles to provide visual learning in the IDT field (Guney, 2019a; 2019b; Ipek, 2003). For effective and efficient HCI processes, all design variables in the user interface should be used to develop effective and high-quality visuals in ID. In literature, UID, UED and interaction design have close relationships based on their characteristics in the field of ET as software applications. Interaction is the design process between learners and materials. The aim of the interaction design is to create instructional materials that enable the learners to gain their objectives in the best technique with instructional and visual design processes as well.

As a result, HCI deals with designing strategies of visuals as well as instructional development for learners and teachers. For this purpose, interaction design should include screen design variables, screen density, nodes, links, images, fonts and icons that users interact with. In addition, physical objects, time and behaviour are the other dimensions to supplement interactive design for learning with visuals. On the other hand, to provide HCI for designing visuals in learning, all researchers, designers and teachers should aware of evaluation methods for UCD in the field of IDT. The methods explain learning strategies for developing interface design as well as creating effective instructional

and visual designs in the instructional environments based on ID models for learners and interface designs.

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