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Exploring Language Learners' Cognitive Processes in On-line ESP Courses via Think-aloud Protocol Analysis

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Abstract

The present study aims to investigate language learners' cognitive processes in on-line ESP courses. Three modes of inquiry are used: think-aloud protocol analysis, screen capture analysis, and correlation analysis. The theoretical foundations for the evaluation of the cognitive aspect of Ferdowsi Univeristy of Mashhad E-learning System are drawn from cognitive load theory, cognitive apprenticeship theory and human-computer interactivity theory. 15 users were interviewed while their performance on the screen was recorded electronically. The results of qualitative and quantitative analyses show that design features have a meaningful effect on the users' performance in four phases of cognitive interaction with e-learning systems. The educational implications of the findings for software developers are discussed.

Keywords: E-learning, Cognitive Processes, Think-aloud, Cognitive apprenticeship, Instructional Design.

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1. Introduction

The significant place of e-learning modules in today's educational curriculums cannot be denied. The logistical advantages of e-courses motivate education centers and universities all over the world to develop and expand their e-learning systems. Like any other instructional enterprise, these systems can flourish and promote only if proper needs analysis and evaluation components accompany them through their creation and developmental phases. This evaluation may be directed to different dimensions of e-learning programs. One of the neglected areas of research regarding the evaluation of e-learning system is their users' cognitive processes. Due to the difficulties which are associated with tracking participants' cognitive processes in on-line courses, few studies have explored this area of research (see Baldus & Nicholas, 2010; Kalyuga, 2007; Sorden, 2005). However, cognitive processes can be effectively explored using recent techniques of inquiry developed in the field of think-aloud protocol analysis (TPA). This study aims to use protocols as the main data pool for investigating the e-students' cognitive processes in on-line courses. The tracking data extracted from screen capture analysis and correlation analysis conducted on the quantitative data extracted from the protocols through content analysis were also used to supplement the results of protocol analysis.

2. Review of the Related Literature

In this section first distinctive features of e-learning versus traditional learning are introduced. Then the place of cognitive studies in the development and evaluation of e-learning systems is discussed. In the next step, the researchers elaborate on the basic concepts in cognitive load theory and its application in e-learning projects. Afterwards, think-aloud protocols and their distinctive characteristics are reviewed. In the final part, the main proposal of this study i.e.

using TPA to build an evaluation program for cognitive processes in e-learning systems is explained in detail and a framework for directing think-aloud sessions is delineated.

2.1. Traditional Learning vs. E-learning

Learning does not happen in vacuum; it develops in a context of interaction between the learners and another party such as a teacher, a text, an experience, an object or a machine. Each form of learning brings with itself a certain number of assumptions and limitations. E-learning has distinctive features that cannot be observed in traditional classrooms. The evidence for such features can be found from different perspectives. In addition to building machines, we interact with them (Schuman, 1987); having a successful interaction with computers depends on the design of the interface through which human and machine interact. While in traditional learning environments, all the human parties are intelligent enough to adapt to the ever-changing complex of contextual factors and react to the others' social, emotional, and psychological actions, an e-learning system has to be designed and programmed to be able to reach an acceptable level of interactivity. Developers of on-line learning system, instead of relying on the teachers' and students' intelligence, have to anticipate most of the possible situations in learning and become prepared to deal with them. This requires a level of knowledge and insight into the nature of learning and learning processes which cannot be gained in a single field of scientific inquiry. Thus the findings of a wide range of disciplines such as psychology, intelligence studies, instructional design, critical pedagogy, information technology and software engineering are being used to build successful learning systems worldwide.

Out of the three types of interaction which are possible in traditional classrooms (Moore, 1989) namely learner-instructor interaction, learner-learner interaction and learner-content interaction, only the third one exists in most of the e-learning systems. One can understandably expect the learner-content interaction in e-learning systems to be considerably richer than its counterpart in traditional classrooms so that the absence of classmates and the instructor can be compensated to some extent. This makes the job of system designers and developers harder in terms of meeting engineering standards and psychological context. von Brevern (2004) induces that in e-learning systems, the content delivered to the learners must be pedagogically and psychologically valid. The absence of the instructor in most e-learning system leaves no choice for the pattern of autonomy other than a learner-centered one. Therefore learner variables such as cognitive style and cognitive strategies must receive additional attention in the development and evaluation of e-learning systems. Principles of instructional design (Gagné et al., 1992) and principles of cognitive learning (Clark & Mayer, 2002) must be observed in the creation of e-learning softwares. To implement such principles in e-learning systems, von Brevern (2004) suggests using an object-oriented design in which learning content is distributed across multiple learning objects designed based in the learner variables particularly cognitive factors.

2.2. Cognitive Processes in E-learning

Some scholars see e-learning studies as an interdisciplinary field of research that spans philosophy, psychology, cognitive sciences, discourse analysis and critical pedagogy (see von Brevern, 2004). During the last decade, more educational psychologists have attended to the importance of theorizing cognitive aspects of e-learning (see Albert & Mori, 2001). Ekanayake, Karunarathna and Hewagamage (2006) open a new horizon in the study of cognitive processes in e-learning and propose an architecture for affective e-learning. Drawing the findings in affective computing and educational psychology, they argue for the necessity of electronic equivalents for emotional, cognitive, social and behavioral factors which have been long establaished in conventional classroom research. They explain how cognitive scientists have been ignorant to the role of emotion in cognition and claim that this has recently changed (see Davis, 2000; Hudlicka, 2004). Based on this view, designers of e-learning systems have to be careful about different types of emotional and psychological reactions the program might stimulate in learners if they are to promote their cognitive skills. Ekanayake, Karunarathna and Hewagamage (2006) propose a cognitive architecture for affective e-learning. They argue that emotive and cognitive aspects of computation are closely related and consequently any design for an effective e-learning system should account for its impact on the learners' cognition and emotions. In their study, they use a range of physiological and psychological techniques to record and analyze signals coming from the learners interacting with e-learning system. In the architecture proposed for affective e-learning, updating learner cognitive profile and building a cognitive decision making module play a vital role in maintain the stability of the human-computer interaction and increasing the efficiency of the e-learning system. They believe that usually a gap is created between the learner's natural cognitive model the system perceived cognitive model of the learner as a result of the lack of sufficient transformation methodologies. The e-learning system used in this study is equipped with a database including all the earners' cognitive profile and starts to record and interpret the physiological signals coming from them during the interaction. The combination of these two sources of information provides the system with a range of options for the content and form of the learning objects that are compatible with each particular learner's cognitive and emotive style. Although implementing such complicated and expensive e-learning systems is not feasible most of the time, the cognitive approach used in this study can be tailored to other types of systems to incorporate learners' cognitive variables into the design and evaluation of the system.

Salmon (1998) offers a list of cognitive skills that can be observed in on-line learning systems:

> … offering ideas or resources; inviting critique; asking challenging questions; articulating, explaining and supporting positions on issues; exploring and supporting issues by adding explanations and examples; reflecting and re-evaluating personal positions; critiquing, challenging, discussing and expanding ideas of others; negotiating interpretations, definitions and meanings; summarizing and modeling previous contributions; proposing actions based on developed ideas. (pp. 6-7)

Fox and Mackeogh (2003) used Ohlsson's (1995) list of cognitive skills to compare the high-order thinking activities in two on-line groups of students. The did a content analysis on the material being produced by the students in order to tag the discourse used in peer-tutoring or on-line discussions based on the categories proposed by Ohlsson. They came up with two final conclusions. Firstly, content analysis of students' contribution to the on-line course was very successful in conceiving their engagement in high-order cognitive skills. Secondly, assessment is a key element in motivating the students to participate in on-line activities.

Hooper and Hannafin (1991) maintain that not only understanding e-learners' cognitive processes is very imporatnt for system designer but also this understanding must be used as the base for instructional design. They define 4 cognitive phases: retrieving, orienting, presenting and encoding. Richter (2007) proposes 11 strategies to promote cognitive processes during these 4 phases. Her framework is a hybrid of Hooper and Hannafin's (1991) proposal regarding the cognitive phases learners go through, Cognitive Load Theory and her own theory "Cognitive Interactivity".

2.3. Cognitive Load Theory and E-learning

According to Kalyuga (2007), the main focus of any evaluative program for e-learning should be efficiency not effectiveness. Any poor program does have some effect; the question is that is it worth it, given the mental effort and cognitive load imposed on the students? Cognitive load theory explains how the limitations of working memory (WM) may affect learning and performance. The nature of changes in long term memory is slow and incremental. WM functions as a bottleneck and slows down the flow of new information into LTM. This happens because most of the time, WM has to be allocated to default problem-solving mechanisms that become active in the absence of external sources of knowledge; few space is left for organizing knowledge structures and incorporating them into the available knowledge accumulated in LTM, hence the undesired conditions for learning. Nevertheless, research shows that our mind does function even in the most complex and challenging situations so there must be another mechanism which covers for the limitations of WM.

Sorden (2005) emphasizes the importance of avoiding unnecessary cognitive load in the design of on-line instruction. As he explains, because the effect of distracters that load the learner's mind with irrelevant information is considerably more in virtual environments, it is imperative that evaluative research projects diagnose and report the sources of waste of energy caused by such instructional distracters in e-learning. Actually these distracters waste mind's brilliant ability to shrink working memory's limitations by the use of schemata.

Therefore one can see that theoretically engaging in mental activities that are not the main focus of instructional e-

2.4. Cognitive Apprenticeship Framework

Cognitive apprenticeship is an instructional framework which focuses on types of knowledge needed for developing required expertise (Collins, Brown & Newman, 1989). In online learning it is translated into the arrangement of design features which must be organized based on the objectives of the course. There are six instructional methods that can be used to promote cognitive apprenticeship: modeling, coaching, scaffolding, articulation, reflection and exploration. According to Parscal and Hencmann (2008), the nature of online systems as the medium of learning can lend itself to scaffolding and exploration more than the other methods. Users' learning process while interacting with e-learning systems is usually build up with scaffolding and moves toward more exploratory options in more advanced levels. In the present study, we use these two basic concepts to analyze and interpret screen captures which reflect users' interaction with the e-learning system.

2.5. E-Learning Usability Evaluation via TPA

Richter (2007) introduces important strategies to improve cognitive processes in human-computer interaction. In the present study we use the main ideas of these strategies to develop a set of instructions that direct the participants' verbal protocols toward explaining the target cognitive processes. Richter defines 4 cognitive phases namely enabling retrieval, orienting, presenting and enabling encoding. The first cognitive phase (enabling retrieval) consists of 4 steps: organization, integration, transfer, and retrieval plan. The second and the third phase each happens in a single step. Orienting is realized when the learning context is enabled and presenting occurs when learners face the learning materials. The fourth phase (enabling encoding) includes 3 steps: cognitive practice, metacognition and cognitive dissonance.

3. Method

The core of the present study's design is formed around think-aloud protocol analysis as a qualitative mode of inquiry. However, the interpretation of protocols is accompanied by quantitative accounts of screen captures and correlation analysis is used to investigate the relationship between these two contexts. The procedure of the study is explained in the following sections.

3.1. Participants

The participants of this study include 15 e-students of the electronic courses provided by Ferdowsi University of Mashhad. All the participants were informed about the general objectives of the evaluation project lunched trough this study and were assured that the information they share with the researchers will be confidential and used anonymously. They included 8 males and 7 females and their age ranged from 19 to 28. None of the participants were technophobic and all of them knew how to work with the e-learning system; this was checked through a pilot session by giving basic instructions to the students and monitoring their interaction with the system.

3.2. Instrumentation

Three sets of instruments were used in this study. The first set comprised the e-learning system including all the software and hardware facilities needed for lunching and utilizing the on-line programs. All the consoles were connected to the university's e-learning system though a LAN. The main on-line application was provided by commercial parties and then customized by Iranian programmers to suit the objectives of the e-learning program designed by Ferdowsi University of Mashhad. All the menus and links were in Persian and the content of the e-lessons was created by a range of documentation and graphic softwares such as Adobe Acrobat, Microsoft Word, Photoshop etc. Three E-courses visited by the participants in this study were as follows:

- E-course No. 1: including only text files in the html, Word, and PDF formats (Topical Interpretation of Nahjol-Balaghah for the students of Theology)
- E-course No. 2: including text and graphic files in the jpeg, png, and gif formats (Physics for the Students of Engineering Majors)
- E-course No. 3: including an interactive application originally designed and specifically developed for the system (ESP for the students of Basic Sciences)

The second set included the documentation instruments. A digital sound recorder was used to document the participants' think-alouds and a screen capture application (embedded in Camtasia Studio software) was used to track, monitor and save the visual record of the participants' interaction with the system.

The third instrument was the protocol extraction checklist designed by the researchers for directing the think-aloud protocols. It included a set of general rubrics which were given to the participants in the written form regarding the procedure of the TA session and the type of answers expected from them. The modeling think-aloud session held by one of the researchers was recorded and played for all the participants to ensure they have a vivid image of the procedure of the desired think-aloud sessions. The items included in the checklist based on the literature helped the researcher to keep the track of protocols almost on the same line. These items worked as check points which were managed by the researchers to guide the participants to produce information which was research-worthy. All the items were designed in relation with the general structure proposed by Richter (2007) for the four cognitive phases of human-computer interaction.

4. Results and Discussion

The qualitative and quantitative results of the study of the e-students' cognitive processes are organized into 3 sections: protocol analysis, screen capture analysis, and correlation analysis.

4.1. Protocol Analysis

The participant's think-aloud protocols were analyzed to explore their cognitive processes and identify the problems and prospects of the e-lessons presented at the university's e-learning system. Different aspects of the e-lessons mentioned in protocols are here associated with the four phases of cognitive processes introduced by Richter (2007) and the possible reasons of participants' reaction to the strong and weak points of the system are discussed using her framework. Since the verbatim transcriptions of the whole sessions are too bulky and sometimes redundant to be presented here, only a few representative samples are provided to illustrate the nature of the qualitative findings. In addition, along with Richter's framework, more recent work on the usability of e-learning systems (see Van Den Hakk, de Yong & Schellens, 2004) is used to enrich the arguments. The following excerpts reflect some of the main weak and strong points mentioned in the protocols.

Sample No. 1:

> *I don't know where to begin; there is a lot of stuff on the page and it is quite confusing for me. I think it was much nicer if I was exactly told what to do and how to proceed.* (Protocol 1, E-course 1)

Here the user is almost paralyzed because of the confusion created by numerous headings and menus on the first page of E-course 1. This is just one example of frequent complaints which were expressed by the participants during the interviews. It seems that designers of the system were more concerned with creating more synchronic links on the page rather than guiding the users through clear diachronic steps. This issue is addressed by many scholars who have done evaluation projects on e-learning systems (see Richter, 2007).

Sample No. 2:

> *There are no pop-up balloons on the links when I direct the cursor over them. They have short names which are not telling so I have to click on them and go to another page to see what happens. For example this one,* [the participant refers to one of the links on the page with the cursor] *well, it says "getting backups of the content". Now I am asking myself what type of content? What type of backup?... You see I have to go there to see how it works.* (Protocol 1, E-course 2)

The above excerpt shows the significance of explaining tags which can appear near different links giving the users a brief insight to the function of that link. Such tags can buy valuable time and save users' energy. Although clicking on the links and observing the contents of the target page may seem a reasonable alternative to tags for some designer, this sample and many other similar cases observed during the interviews clearly show that the lack of such explaining tags can increase user's frustration and reduce the efficiency of the e-lessons to a considerable degree. This is one of the occasions in which simple design features may cost great amount of energy for the users of the system.

Sample No. 3:

> *What is this?* [looking at the pop-up balloons that appear when the user clicks on different parts of the table of contents]*... I think this is ridiculous! Why there should be balloons that merely repeat the titles already shown in the table of contents. Instead of this, they could put more informative explanations here so I wouldn't need to read inside the links to see what they are about.* (Protocol 2, E-course 1)

This sample shows that the mere existence of explaining tags cannot guarantee users' satisfaction. The comments included in the tags must be telling and informative enough so that the users can make more informed decisions while navigating the site. Using tags which only repeat the title of a link or provide some other obvious information is a relatively frequent phenomenon in educational web pages. As it is seen above, the accumulation of the affective impact caused by such trivial design mistakes may gradually eat away users' trust and eventually result in them getting cold feet for using the e-learning system.

Sample No. 4:

> *I do not want to see all things together. I prefer it to proceed as in a traditional classroom; the teacher starts from somewhere and gets to a specific point. There I can follow the flow of the lesson but here I have*

> *to make all the decision and the worst part is that I cane never be sure whether I am doing it all right. I usually avoid using this system; many times I have to call my classmates and ask them what to do.* (Protocol 11, E-course 1)

The comparison made by one of the participants in Sample No. 4 reflects a crucially important point which must be taken seriously by designers of all e-learning systems and that is e-student come to the system with pre-constructed mentalities about learning, class, the role of the student and the role of the teacher etc. Therefore, in many occasions the functionality and value of the e-counterparts of learning elements are judged against the standards created by these mentalities. Despite the fact that users' expectations of an e-learning system may be educationally justifiable or not, the designers of the system cannot stay indifferent to the affective impact caused by the traditional-versus-electronic comparisons which are naturally made by the users. The above excerpt shows that while making navigating decisions, users expect the simulation of the real class i.e. the e-course to guide them through the same steps which are usually taken by the students in traditional classes. Therefore, in addition to taking design standards into accounts, designers of the system have to be familiar with the nature of activities which are conventional in the courses held for the related subject matter.

Sample No. 5:

> *They give us long lists including the activities we have to perform or our duties as e-students; well I am not a reading person that much. Even if I do read those lists I'll probably forget many things not more than few minutes later; so what's the use of them? Wasn't it better if they informed us every time something was*

> *up? I am not sure, maybe there is something wrong with ME!?* (Protocol 5, E-course 2)

The above statement shows the effect of one of the participant's learning style on the level of interaction he can maintains with the e-course. This single sample reminds us of the necessity of transferring the body of knowledge which is constructed during the recent decades about learning styles and strategies into e-education. The complexities associated with the impact of learning style on the outcome of teaching are even more in online course for two reasons. First because many aspects of learning style which come to the surface via physical performance of the students are not accessible for the teachers and designer; therefore many possible styles must be assumed and accounted for by using alternative layouts or different combinations of navigating options. Second, the unique qualities of multi-media tools and the educational effects they may offer along with the complications which are developed as a result of hybridization of different types of literacy (visual, textual, computer…) altogether make the task of instructional design more demanding. One of the possible solutions for dealing with this problem is conducting a rigorous needs analysis phase from which some of the design criteria may be extracted to adapt the e-learning system with the characteristics of the target community.

Sample No. 6:

> *I like this lesson very much. Everything is sufficiently explained. I know exactly what to do. The program has vivid colors and the fonts are beautiful. When I read something on-line I like it to be neat. Really motivates me to go on and explore more things. I wish all lessons were presented like this one* (Protocol 4, E-course 3)

The above comment was made in response to one of the e-courses which was designed for teaching English to the students of basic sciences. Among others, two factors that seem motivating for this participant are clarity of link functions and aesthetic value of the design features. The latter is even more important in comparison to the traditional material. The affective impact of colors on the computer screen is sharper than the printed page because at each moment the users allocated more centered attention to the links on the page as the only option they have; therefore the design choices made by system developers play a very important role in building an effective relationship between the system and its users.

Sample No. 7:

> *Oh God, just look at this. After all these links eventually they are giving me just a PDF file. I really think they are wasting our money… couldn't they just put on the university site's FTP? I have seen e-learning systems in other countries. They are interactive, interesting, but this…* (Protocol 10, E-course 1)

Comments such as the above sample are not very rare in the protocols collected in the present study. They are addressed indirectly to the system developers and e-teachers and question the justifiability of learning material and the mode of teaching used for presenting them to the students. E-lessons offer several opportunities to the teachers to present the subject matters in different shapes and forms; actually the diversity and flexibility of multi-media lesson is expected to be one of their main advantages over the traditional learning materials. Ignoring these opportunities reflects teachers and developers' negligence toward a very important issue which affects students attitude toward the whole program i.e. justifiability of the e-courses. Ignoring this issue will result in undesired outcomes in the long run.

Sample No. 8:

> *There is no activity for me. The only thing I can do is reading which is really boring and it becomes even worst when there is no teacher to force me to do so. I wish I could write here or at least answer some questions.* (Protocol 3, E-course 1)

Users should be given several options in different modes of interaction with the system; this will reduce their frustration and add to their tolerance while working on the e-lessons. The overreliance of a certain instructional pattern or a specific skill cause boredom as it is obvious in the above comment. The diversity of representation that can be implemented synchronically in online environments is a potential that must be exploited by the designers to maintain users mental and physical presence on the line.

Sample No. 9:

> *Now I am thinking where to begin… let me see… uh… there are some lessons on the right side, and… some links here at the middle… some menus up there… it is really confusing…* (Protocol 9, E-course 2)

In a few occasions in which the menus and options were presented one step at a time, comments such as sample 9 did not occur. The temporal sequence of online learning procedures can only be regarded if the spatial arrangement created by the design features supports it. The temporal sequences are built up out of the navigating choices made by the users and these choices are dictated by the options which must be realized in spatial terms. The close relationship between the temporal and spatial dimensions of an e-learning system is an undeniable issue which affects the outcome of the program considerably.

Sample No. 10:

> *This is good. Although the lesson is English, there are clear instructions in Farsi that tells me what to do. At any moment I need only to think about one thing and choose from a few available options.* (Protocol 7, E-course 3)

Cross-linguistic explaining tags attached to the hypertext links on different places of the e-lesson are provided to help users connect with the items and use them in an optimal way to their benefit. This comment was made in response to the Farsi explanations which were attached to English menus of an online software embedded in E-course No. 3 under investigation in the present study.

4.2. Screen Capture Analysis

439 minutes of screen captures were analyzed to find meaningful moves in e-students' exploration patterns and their possible interaction with the instructional scaffolding provided by the learning objects embedded in the e-learning system. Although at some occasions, the captures were used to make sense of the recorded think-aloud protocols, they were mainly explored to investigate the reflection of the e-students' cognitive challenge on the screen. Cursor minor moves and participants' explanations provided the researchers with a network of decision making mechanisms that could be meaningfully interpreted and related to the human-computer interaction observed in the working sessions. Diagrams 1, 2 and 3 present the cognitive steps followed by the participants in E-courses 1,

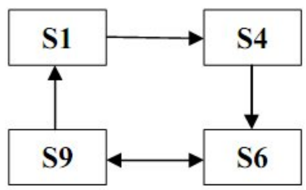
2, and 3 respectively. S# labels represent the 10 steps defined within the four phases of cognitive interactivity (see Table 1).

Table 1. *Rating Criteria for Analyzing Screen Captures and TA Protocols Adopted from Richter (2007)*

	Cognitive interactivity reflected via ***TA protocols***	*Needed instructional design observed via* **screen captures**
Phase 1: *Enabling retrieval*	**Step 1:** realizing the value of the lessons	Identifying the benefits of the knowledge presented to the system users
	Step 2: economical navigation through the hierarchy of the lessons	Creating manageable chunks (titles, subheadings, modules etc.)
	Step 3: ensuring the mastery of the previously presented knowledge	Asking questions and giving feedback
	Step 4: building new knowledge upon the previous one	Facilitating links and internal cues to the existing schemata
	Step 5: ensuring the mastery of newly presented knowledge	Presenting drills and exercises
	Step 6: facilitating retrieval	Using site maps
Phase 2: *Orienting*	**Step 7:** Orienting to the new knowledge	Providing Games, simulations and advanced organizers
Phase3: *Presenting*	**Step 8:** Dual encoding	Dual presentations e.g. using visual and narrative modes to impart the new knowledge
Phase 4: *Enabling encoding*	**Step9:**making decisions through the learning environment	Presenting worked examples instead of problem-based learning
	Step10: checking one's progress through activities (metacognition)	Providing explicit feedback in tasks using the new knowledge

Diagram 1

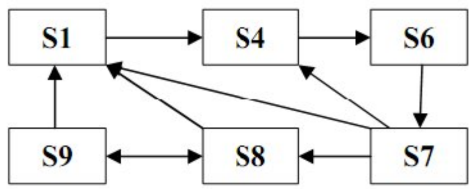
Cognitive Steps in E-course 1 (textual)



In E-course 1 which is composed of written material stored in text files, the students take the first step of cognitive interactivity by realizing the value of the presented e-lessons; this is achieved through a series of introductory passages which are provided by the instructor and can be browsed via the site menus. However, the students fail to take the second step (economical navigation) and the third step (ensuring the mastery of previous knowledge) in phase 1 (enabling retrieval). This is due to the lack of enough titles and modules that are needed for efficient navigation and also the lack of instructional feedback. Thus the students have to jump to step 4 (building new knowledge) which is a shaky move because the success of step 4 is closely related to the realization of step 3. Since no drills or exercises are provided in E-course 1, the students cannot take step 5 (ensuring the mastery of new knowledge) and have to take another leap to step 6 (facilitating retrieval) using the site map. The lack of advanced organizers and other modes of presentation (graphic objects etc.) deprive the students from phase 2 (orienting) and phase 3 (presenting) of cognitive interactivity and leaves them with no other choice but taking step 9 (making decision through the learning environment). The unilateral flow of knowledge from the texts to the students' mind without giving any feedback from the instructor renders step 10 (checking one's progress) practically impossible; this means that the fourth phase of cognitive interactivity (enabling encoding) fail to be fully realized in E-course 1.

Diagram 2

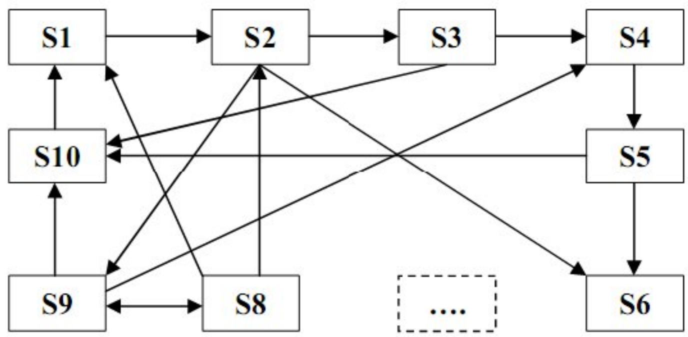
Cognitive Steps in E-course 2 (textual & visual)



E-course 2 includes more facilities for cognitive interactivity because other than steps 1, 4, 6, and 9 which are realized in a textual E-course, the existence of visually diverse objects in the form of diagrams, animation, and photos builds the instructional design needed for the realization of phases 3 and 4 possible. Graphic objects in E-course 2 are used for presenting advanced organizers that let the students orientate to the new knowledge. In addition, the visual elements added to the text material provides the student with step 8 (dual encoding) which in turn amplifies steps 9 and 1. Of course, E-course 2 still lacks steps 2, 3, 5, and 10. This means that retrieval (phase) is only weakly realized and encoding is not thoroughly enabled due to the lack of feedback. Students must receive feedback to be able to build their metacognitive strategies (Richter, 2007). Feedback can only be provided in an interactive environment which makes the mutual flow of knowledge possible. Actually this is the main motivation behind the preparation of the interactive programs such as E-course 3.

Diagram 3

Cognitive Steps in E-course 3 (textual, audio-visual, & interactive)



The interactive nature of E-course 3 provides a range of instructional opportunities which are missing in the other two E-courses in this study. The cognitive gaps, observed in phases 1 and 4 of cognitive interactivity, are appropriately covered by new interactive design elements in the on-line application embedded in E-course 3. There are certain menus which can be used by the students to do exercises, answer questions and check their progress. In addition, both content materials and instructional rubrics are presented in manageable chunks (e.g. instructional items presented one step at a time at the center of screen) which let he students to navigate economically through the hierarchy of the e-lessons. The design problem observed in E-course 3 is the lack of visual elements. Step 7 of cognitive interactivity (orienting to the new knowledge) cannot be realized only by relying on interactive structures; other modes of presentation should be included so that the third phase (orienting) can be realized in E-course 3 hence completing all the cognitive steps required for desired human-computer cognitive interaction.

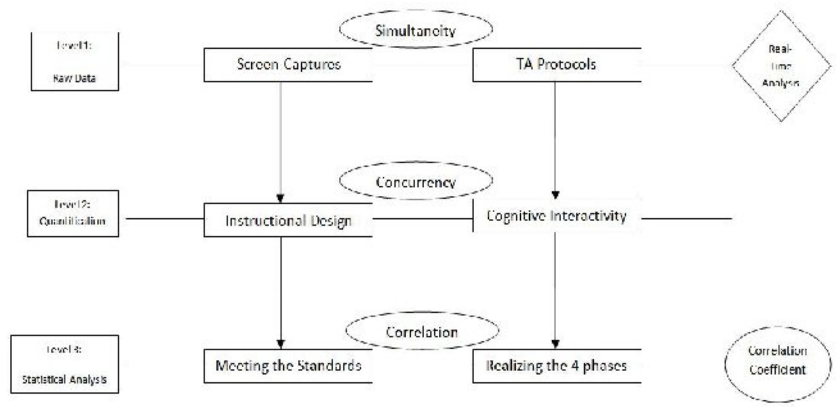
All in all, the results of screen capture analysis show that proper scaffolding realized though the learning objects in the system reduces the number of redundant cursor moves and makes e-students' exploratory decisions more to-the-point and efficient. This scaffolding may be implemented in the steps which are designed using hypertext capabilities or by providing explanations which makes the task of learning more coherent. Learning objects which are tagged by enough explanations are less frequently and more efficiently visited by the users whereas those learning objects which are not adequately tagged may receive frequent but confused visits from the users. Analyzing the sequences of the e-students' moves on the screen shows that main headings are usually in the center of attention and, if designed meaningfully, can save time and energy for the students. In addition, users' reaction to static and interactive learning objects can be differentiated using the captures. In most cases, the interactive design features led to more informed decisions and more efficiency; however, in some occasions, due to the inadequate explanations, interactivity of the learning contexts created more confusion. This shows that interactivity and clarity of learning objects are two important aspects of instructional design which are closely related and guide e-students' exploratory moves through proper scaffolding.

4.3. Correlation Analysis

In the present study, correlation analysis was used to investigate the relationship between e-students performance in the four phases of cognitive interactivity and instructional design of the e-learning system. It must be mentioned that the data sets used for correlation analysis were extracted via content analysis and translated into observable quantities that can be entered into SPSS. This was done to supplement the qualitative findings presented in the previous two sections with statistical results provided hereafter. Diagram 4 demonstrates a general outline of the quantification process.

Diagram 4

Quantification of Qualitative Data for Correlation Analysis



The quantification of the instructional design as the independent variable presenting the quality of the E-course was done by counting the frequency of design elements (Richter; 2007) observed in the screen captures. For example, each of the explanations provided in the E-courses identifying the benefits of the knowledge presented via the e-lessons was counted as an instructional design feature contributing to step 1 of cognitive interactivity. The realization of this cognitive step in the mind of the system users was quantified by counting the evaluative utterances observed in the protocols revealing what students thought regarding the value of the e-lessons. Another example that can be mentioned to illustrate the quantification process is the frequency analysis of step 2 (economical navigation). The students were asked to explain about the moves they made across the links (within the html files or in the menus) and articulate why they are making that move. Each of these explanations was then interpreted to determine the efficiency of the moves and judging the economy of the navigation in general. That is to say the frequency of the efficient moves (as expressed by the students) was taken as the quantified realization of this cognitive step. The design counterpart of this step as proposed by Richter (2007) is the existence of manageable chunks in the E-course. Therefore, the frequency of the chunks of knowledge (independent passages, pictures etc.) was taken as a measure for this design feature. All of the other cognitive steps and their associated design features were quantified in a similar way based on the frequency of the observed utterances (in the protocols) or design elements (in the screen captures).

Each participant's TA protocol was used for rating the realization of the 10 steps needed in cognitive interactivity framework, and each participant's screen capture was analyzed to rate the implementation of the desired instructional designs needed to realize the cognitive steps associated with them. Eventually the average of these ratings produced two sets of scores one representing the participants' cognitive performance and the other one showing the design quality of the E-courses. The correlation analysis shows that there is significant relationship between the e-students performance in the four phases of cognitive interactivity and instructional design of the e-learning system. The correlation coefficient of 0.67 suggests that when design features of the e-courses are closer to the instructional standards, users can complete the pour phases of interactivity more successfully producing better scores through the 10 steps of cognitive interactivity.

5. Conclusion

To draw conclusions, the findings of this study are put together along with the results of the previous empirical research and are analyzed against the theoretical foundations proposed by instructional designers and e-learning experts. The findings of think-aloud protocol analysis, screen capture analysis and inferential statistics are combined to triangulate the coordinates of the cognitive outset of Ferdowsi University of Mashhad's e-learning system.

The analysis of think-aloud protocols based on the human-computer interactivity framework proposed by Richter (2007) show that most of the problems which prevent users from using the potentials of the e-learning system are caused by uniformed design features; such features are more obvious in first and fourth phase of interactivity framework namely enabling retrieval and enabling encoding. Participants of the study frequently mentioned problems they faced in the first phase; the analysis of the protocols shows that these problems appear because the learning materials are not interactive, digestible, and meaningful enough. According to Clark (2003), transitions, headings, summaries, topic introduction and learning objectives are among the important tools that must be used by material designers to help users orientate themselves to the objectives of the e-learning system. The results of the present study are in accordance with Clark's view. The synchronic analysis of protocols and the screen captures associated with them show that whenever participants had problems in the "enabling retrieval phase", appropriate headings were and topic introductions missing in the design features of the system.

There must be a balance between near transfer and far transfer induced by the e-learning materials. These two terms are defined in the "enabling retrieval" phase of Richter's (2007) framework. Near transfer refers to the activation of presented material using working memory and far transfer refers to the connections made between the current learning and previous knowledge stored in long-term memory. According to Gagne (1985 cited in Richter, 2007), the best way to maintain the balance between the two is presenting a hybrid of inductive and deductive learning patterns. The results of protocol analysis show that in many occasions the learners could not connect to the material because the e-lessons were biased toward inductive or deductive reasoning. Over-reliance on inductive learning put learners' working memory under pressure and overuse of deductive patterns become boring after a short while. When near and far transfer were appropriately combined, participants reported few problems in the "enabling retrieval" phase.

Encoding is the last and most important cognitive phase in Richter's (2007) interactivity framework. According to her, for "enabling encoding", users' cognitive and metacognitive skills must be challenged through practice. The results of the protocol analysis show that when design features put e-students in practice contexts, they find the opportunity to enable their encoding potentials. In contrast, when lessons were finished with no practice or questions, the users felt abandoned and doubtful. It can be argued that the autonomy of the learners in online systems can work against their benefit if it is not guided with a reasonable design based on the nature of material and objectives of the course. The ultimate objective of the e-learning systems is to simulate merits of real classrooms and if possible create contexts which may not be even feasible in traditional context. To this end, one cannot deny the necessity of practicing the newly learned knowledge. Logically there must be design features allocated to apply this principle. E-lessons must be accompanied by relevant e-practice.

The screen captures of e-students' interaction with the system were analyzed based on the cognitive apprenticeship framework proposed by Parscal and Hencmann (2008). The results show that the lack of enough scaffolding takes e-students' explorations in the design features of the system astray and wastes their educational efforts. E-learners' autonomy can lead to desired cognitive apprenticeship only if learning contexts are build up in meaningful steps which are neither too light nor too heavy regarding the cognitive load they require. Cognitive apprenticeship, as a framework for interpreting learning sequence, shows that learning objects in an e-learning program must cling to a whole scaffolding structure which is dynamically arranged based on the potentials of its users. Otherwise, as it was observed in the screen captured collected in the present study, e-learners' exploration through numerous headings and several menus can only add to their confusion. In the quantitative section of the study, the results of the correlation analysis show that there is meaningful relationship between the instructional design of e-learning systems and students' performance in the four phases of cognitive interactivity.

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