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RELATIONSHIP BETWEEN BRAIN-BASED LEARNING STYLES AND BEHAVIOURAL LEARNING PATTERNS IN WEB-BASED EDUCATIONAL SYSTEMS

[1] MOHAMMED AHMED GHAZAL, [2] NOR AZAN MAT ZIN, ZURINA MUDA

1, First Author, **2,Corresponding Author* Centre for Software Technology and Management Research (SOFTAM), Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM BANGI, Selangor, Malaysia

E-mail: mohammed.ghazal@gmail.com, {azan, zurina}@ukm.edu.my

ABSTRACT

Web-Based Educational Systems (WBESs) deliver the same design features such as learning content and user interface to all learners. However, learners have different preferences according to their brain structures. The brain dominance determines how learners prefer to learn, communicate, collaborate and solve problems effectively. Tracking learners' behaviours within the WBES is an essential approach to predict the learners' Learning Styles. Therefore, the relationship between learners' behavioural interactions in WBES and Learning Styles should be examined. This study investigated the learning patterns of 69 respondents within WBES with respect to Herrmann Whole Brain Model (HWBM) Learning Style. Results showed that there is a significant correlation between some learning patterns and HWBM Learning Styles. The most preferred features for designing WBES according to Learning Style model were also identified. The results can be used for developing an adaptive learner model.

Keywords: *Herrmann Whole Brain Model Learning Style (HWBM LS), Behavioural Learning Patterns, Design Features of Web-Based Educational System (WBES), Learner Modelling, Systematic Observation Study.*

1. INTRODUCTION

Currently, Learning Style is used to personalize the Web-Based Educational System (WBES) [1, 2]. It comprises the learner preferences for describing what he/she likes to do during practicing the learning process. Every learner has a preferred Learning Style which facilitates his/her learning process, improves his/her satisfaction, and makes learning more effective. The most accepted Learning Style definition is stated by Keefe in [3] as "the composite of characteristic cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment". Coffield et al. [4] reviewed and identified 71 Learning Style models; 13 of which were found to affect the tailoring for learning environment. Yet, there is no consensus on standards of the most acceptable Learning Style model for modelling learner preferences in an Adaptive Web-based Educational Systems (AWBES) [5].

BECTA [6] highlighted that Learning Style and cognitive style share the same meaning, and they are sometimes used interchangeably. Whereas, Triantafillou et al. [7] maintained that there are technical differences between the cognitive and Learning Styles; and they do not have the same definitions as mooted in [8]. For instance, cognitive style reflects the cognitive activities (perceiving, thinking and remembering), while Learning Style covers a broader construct, including the behavioural data and physiological styles along with cognitive style. Peterson et al. [5] have also elaborated that cognitive style is related to most innate and intrinsic characteristics, and closely relate to fundamental information processing mechanisms designed according to learner's brain structure; however, Learning Style is a malleable characteristic and it is identified dependently according to domain and environment, where, it reflects the preferred method of responding to learning tasks [5]. Hence, the issue motivate this current study's investigation for a more reliable Learning Style model based on learners' brain

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structure. The brain-based learning theory can be used for modelling the most innate and intrinsic learner preferences effectively by extracting learning patterns of Learning Style model [9]. These patterns are used to identify the learner's learning preferences and styles through tracking his/her behaviour within the design features of WBES. Two main approaches, explicit and implicit (automatic) are used to identify and diagnose the Learning Style [10, 11]. The former approach is the simplest way to identify the learner Learning Style by asking him/her for relevant information via a psychological questionnaire [12]. However, this approach do not provide accurate information about learner preferences, especially those related to learning contents and user interface [13, 14]. Furthermore, Brusilovsky and Millán [15] argued that more investigations are needed to estimate learner preferences related to design features of WBES such as user interface; particularly where the learner preferences towards the design features of WBES are not clear for the majority of learners [16, 17].

It is important to note that literature shows that most of the researches on learner modelling based on Learning Style in AWBES come from the western culture countries, and there is a need to conduct such studies in the eastern culture countries [18]. Using Learning Style for modelling learners towards enhancing the effectiveness of designing a customized learning environment is still highly demanded [19].

This research is almost similar to previous studies [20-22]. However, Graf and Kinshuk [20] incorporated the learner preferences according to Felder-Silverman Learning Style Model (FSLSM) in the Moodle learning management system, while Popescu [21] incorporated Unified Learning Style Model (ULSM) into web-based learning environment called Web-based Educational System with Learning Style Adaptation (WELSA).

The current research uses the mapping between HWBM LS and WBES design features, which cover the learning content and user interface of a WBES design [23] to design an adaptive and automatic learner model for an AWBES. This model is based on behavioural data, and it avoids the problem of an explicit approach of learner modelling, which may occur when asking learners about their preferences in the WBES. According to [23], the investigated mapping are used to propose guidelines for developing WBES according to LS model. The WBES was developed to investigate whether the learner's behavioural data can be used to identify the learner's learning preferences and styles. Therefore, this research aims to examine the significant relationships between learning styles of brain dominance and the respective behavioural learning patterns in order to propose an observable preferences model for learners in WBES according to learning styles. The question addressed in the research is "What are the relationships between learner learning styles of brain dominance and behavioural learning patterns in WBES?" Figure 1 shows the research procedures.

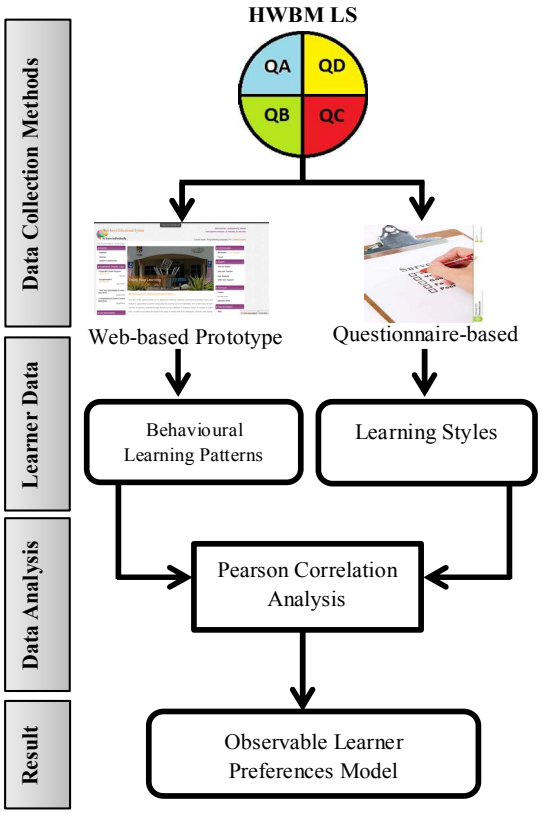

Figure 1: Research Procedure

2. USAGE DATA FOR MODELLING LEARNERS BEHAVIOUR IN WBES

Usage data is an essential type of indirect observation. The log file technique is widely used to gather a learner's behaviour within a web-based systems automatically [24].The log file is used for auditing and tracking learner behaviour by recording a learner's transaction from login until quitting the system. The log file is one of the most effective, reliable and accurate components to acquire behavioural data used to design an implicit approach of learner modelling [25, 26]. The log file

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uses the most common channels (mouse, and keyboard), that are used by the learners to communicate with the system [21].

The log file is normally used to determine learner's demographical information, knowledge level and goals. Currently, log file has other uses; for instance, it is used to infer the learning preferences, interests and learning styles of learners [27]. However, Stathacopoulou et al. [28] highlighted that the main limitation for inferring and identifying learner preferences by analysing the log file is that scattered information may be acquired from the non-sequential behaviour within the different features of a WBES. The behavioural data obtained from empirical studies are limited and inadequate to apply the non-symbolic artificial intelligence techniques such as neural network, machine learning, and genetic algorithm. The non-symbolic techniques are used to infer the unknown knowledge of a learner from the repetitive and entire navigational paths [26]. However, the symbolic formal artificial intelligence techniques such as rule-based, case-based and semantic network are most suitable and effective methods to propose an implicit approach of learner modelling according to Learning Style model [29]. With little interaction information, the system can deduce the learner preferences related to Learning Styles.

Therefore, this study compared the behavioural interactions of learners in WBES with the predefined learning patterns derived from the cognitive science approach. The Learning Style model was used to extract the predefined learning patterns for each style. Additionally, the systematic observation method was used to analyse the most significant patterns according to predefined ones from the usage data. Both of the behavioural learning patterns and the systematic observation method are clarified as follows.

3. BEHAVIOURAL LEARNING PATTERNS IN WBES

This research aims to analyse the behavioural information of learners with design features of WBES with respect to Learning Styles. Learning Style models are used to describe the relationship between learners and their learning preferences in a learning environment by extracting and identifying a set of learning patterns. These patterns represent the attributes, relationships or characteristics of learners within the learning environment [24]. In this study, the learning patterns were identified based on [23].

The HWBM is commonly applied in traditional learning environments rather than computer-based environments [4, 30-32]. The application of HWBM for extracting learners' learning preferences in the WBES needs an investigation of a particular mapping between learner preferences in the traditional learning environment and WBES. Hence, some of the selected patterns within the WBES prototype were based on traditional behaviours and were verified to find out the most significant learning patterns to apply in the context of the WBES with respect to the HWBM in the current study.

Additionally, this study focused on the common design features of a WBES such as learning content, help, support, assignment and test, collaboration and collaborative features. These features were selected based on the brain-based learning theory in which the brain dominance is used to state what and how a learner likes to perform in the learning process [9]. Brain dominance describes what a learner likes to concentrate on; how he/she prefers to learn; what are the most preferred ways to collaborate and communicate with others; and how he/she likes to solve his/her problems and assignments effectively [33].

Furthermore, this study was based on the behavioural indicators, quantifying the learner's interactions within the design features of WBES to be a basis for gathering the behavioural data. The behavioural indicators were as follows: (1) navigational indicators (e.g., number of visited learning objects, and navigation patterns which identify the sequence actions of a learner); (2) temporal indicators (e.g., time spent on learning objects); and (3) performance indicators (time spent and total number of attempts on assessments, quizzes and exercises).

Therefore, this section presents the learning patterns to investigate the relationship of behavioural indicators of learners in the design features of WBES and the learning preferences of learners with respect to Learning Style. The prefix t means "time", h means "hits", and n means "numbers".

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3.1 Learning Patterns of Learning Content Features

The learning patterns associating the learner's behavioural interactions in the learning content features with the learner preferences according to the HWBM Learning Styles are identified as follows:

A. Patterns of Rational Learners. These include *t_Prerequisites, h_Prerequisites* to measure learner preferences towards the logical behaviour through linking the current topic with the previous ones and related topics and requirements; *t_objective, h_objective* to measure learner preferences for determining the learning objectives when studying a new topic; *t_flowChart, h_flowChart* to measure learner preferences towards illustrating and organizing the activities and actions into a logical sequence; *t_Explanation_with_details* to measure learner preferences for reading arguments, details and explanations in order to acquire knowledge; *t_FAQ, h_FAQ* (FAQ is Frequently Asked Questions) to measure learner preferences to learn by reading the common problems and formal answers; *t_References, h_References* used to identify the learner preferences towards using a reliable source of information (e.g., books and articles) to read new topics or to eliminate the confusing terminologies or problems and; *t_syntax, h_syntax* used to reflect learner preferences towards thinking logically through arranging the phrases to create structured and logical statements in a computer language.

B. Patterns of Organizational Learners. These include *t_SlideShow*, *h_SlideShow, n_SlideShow* to reflect the learner preferences towards learning by sequential and organised learning content; *t_exercise, h_exercise, n_exercise* to measure the learner preferences towards learning by answering exercises; and *t_instruction, h_instruction* to measure the learner preferences towards reading and following the lecturers and system instructions.

C. Patterns of Interpersonal Learners. These include *t_introduction*, *h_ introduction* to measure learner preferences of knowing the intended meanings by the writer; *t_tryIt*, *h_tryIt* to measure learner preferences towards performing practical learning methods through using "trial and error" learning method; *t_example*, *h_example* to reflect learner preferences towards learning concepts using practical examples; and *t_video*, *h_video* to measure learner preferences to learn by watching videos.

D. Patterns of Intuitive Learners. These include *t_flash card*, *h_flash card* to measure learner preferences towards visualizing and presenting learning content using small portions of words, numbers, and illustrations with interactive designs. *t_aminationFlash, h_animationFlash* to measure learner preferences for visualizing and explaining the concepts by visualizing and integrating the content in animations using an attractive method to enhance the innovative imagination; and *t_summary, h_summary* to measure learner preferences of reading a brief statement to understand the main points of a concept in an easier way.

3.2 Learning Patterns of Help Design Features

The learning patterns used to measure learner preferences in the help design features according to the Learning Styles of the HWBM, are presented as follows.

A. Patterns of Rational Learners. These include *n_Wiki, t_Wiki* to measure learner preferences of using wikis to obtain more details on any concept that the learner needs; and *n_FAQ, t_FAQ* to reflect learner preferences towards obtaining knowledge about new technology by reading the most frequently asked questions and their formal answers.

B. Patterns of Organizational Learners. These include *n_Wizard, t_Wizard* to measure learner preferences towards using an automatic wizard as sequential guidance that support the learners in achieving their objectives; and *n_brochure, t_brochure* to measure learner preferences towards reading and browsing a brochure catalogue that contains images and brief explanations about the system features.

C. Patterns of Interpersonal Learners. These include *n_VideoTour, t_VideoTour* to measure learner preferences towards using a video to take a virtual tour inside the system in order to obtain more visual explanations about the system components.

D. Patterns of Intutive Learners. These include *t_exploring, n_exploring, t_Syllabus, n_Syllabus, t_Outline, n_Outline, t_*Mindmap, *n_*Mindmap, *t_overview* to reflect learner

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preferences towards using system components, content outline and syllabus to explore and visualise the different components of the WBES in one place.

3.3 Learning Patterns of Support Design Features

The following learning patterns were used to reflect learner preferences in the support design features with respect to the HWBM Learning Styles.

A. Patterns of Rational Learner. These include *n_askTeacherSupport, t_askTeacherSupport, n_askExpertSupport, t_askExpertSupport* to measure preference of learner who tends to ask his/her teachers and experts to obtain support and guidance whenever he/she faces challenges.

B. Patterns of Interpersonal Learners. These include *n_askFriendSupport, t_askFriendSupport* to reflect preference of learner who tends to ask their friends for support and guidance whenever he/she faces challenges.

C. Pattern of Intuitive Learners. It includes *t_thinking* to reflect learner preferences towards spend more time thinking about answering problems.

3.4 Learning Patterns of Collaborative and Communication System Features

The learning patterns that link learner interactions with the design features of communication and collaboration tools and learner preferences were identified and classified according to the HWBM Learning Styles as follows.

A. Patterns of Rational Learners: *n_sendMessgae, n_Message2Expert, n_Message2Expert, and t_emailBox* to reflect learner preferences towards using asynchronous communication channels for communicating and collaborating with teachers and experts.

B. Patterns of Interpersonal Learners: *t_forum, n_forumComments, n_forumMsg, n_postComment, n_post, t_chat, n_chatMsg* to reflect learner preferences towards communicating and collaborating with other friends or with common people, either through asynchronous or synchronous channels.

3.5 Learning Patterns of Problem Solving System Features

The following learning patterns were classified to reflect learner preferences towards the features of problem solving (e.g., assignment, project and evaluation tests) with respect to the Learning Styles of HWBM.

A. Patterns of Rational Learners. These include *n_individualAssignment, t_individualAssignment, n_individualProject, t_individualProject* to reflect learner preferences towards solving assignments and projects individually; *n_test_per_topics* to measure learner preferences in evaluation tests which are conducted according to a particular topic; and *testResult_OpenQuestion, n_openQuestions, t_solutionOpenQuestion* to measure learner preferences towards open-type questions.

***B.* Patterns of Organizational Learners.** These include *n_guidelines, t_guidelines* to reflect learner preferences towards reading and following guidelines and instructions when solving problems. *n_feedback, t_feedback* to measure learner preferences towards reading and navigating feedback; *n_testYourKnowledge, t_testYourKnowledge, n_preQuiz, t_preQuiz* to reflect learner preferences towards solving pre-tests that were used to evaluate a learner's knowledge before starting the learning process for a particular topic.

***C.* Patterns of Interpersonal Students.** These include *n_groupAssignment, t_groupAssignment, n_groupProject and t_groupProject* to measure learner preferences towards solving assignments and projects in groups; *n_memberGroup* to measure learner preferences towards members of a group, where some learners prefer to solve group assignments in a group of two (peer-to-peer) while some learners prefer to work with more than two members.

D. Patterns of Intuitive Learners. These include *n_Whole_Exam, n_ComprehensiveExam* to reflect learner preferences towards answering a comprehensive exam, which evaluates the whole course after accomplishing the learning process for a particular course; and *n_MultipleChoice, t_multipleChoice* to measure learner preferences towards answering multiple choice questions.

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4. SYSTEMATIC OBSERVATION STUDY DESIGN

Systematic observation is defined as an individual approach of quantifying a learner's behaviour. This method focuses on analysing real behaviour observed in a real context. The systematic observation method was conducted in two phases: (1) various predefined learning patterns were defined to represent prospective behaviours of different learners on a WBES; (2) the systematic observation was recorded whenever a learner's behaviour correlated with predefined learning patterns [24]. The systematic observation is classified into non-sequential and sequential methods [24]. This research conducted only the sequential systematic observation, aiming to analyse the observable information of learners for a limited time during practising a limited number of tasks. The main steps for designing the systematic observation study; (1) determining the instrument of data collection; (2) determining the participants who are important to observe; (3) determining the task and a particular place for data collection; and (4) determining the procedures of collecting, organising and analysing the collected data; [34, 35].

4.1 Instruments for Data Collection

4.1.1 Web-Based Educational System (WBES) prototype

The WBES prototype is used to audit, track and analyse learner interactions, leading to identification of behavioural learning patterns, learning preferences and styles of learners. The data requirement for identifying a learner's brain dominance should be diverse and derived from his/her preferences towards different features of a learning environment [36]. The prototype was designed to address the diverse requirements of learners according to the HWBM. It is also used to get additional information about the learner's preferences towards the design features of a WBES using the learner's behaviours of the specific design features.

The prototype provides a number of features to design an online course. These features are designed to implement the predefined learning patterns described in Section 3. Figure 2 illustrates the overall components of these features. The prototype is available at this URL: http://www.ebrain.ps. The features include learning content, help and support, assignments, projects, tests and quizzes, writing notes, communication chat, and 'to-do-list'.

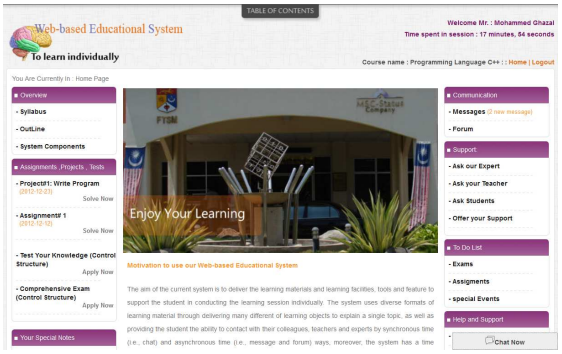

Figure 2: Main Screen of the Web-Based Educational System

4.1.2 Analysis tool

This study also developed an analysis tool to track and analyse a learner's interaction within the design features of WBES. The interactions are stored in each student's log file. The behavioural data is analysed using a refined version of the log file. This version eliminates erroneous actions that occurs whenever the learner is misled in the site navigation to visit a learning object for 3 seconds, or stayed with a learning object more than double this time duration[21].

In this study, the total distinct number of learners' interactions within the WBES prototype is 13,595. The average number of learner actions, for each participant, is 203. The learners' actions are associated with their time stamp and number of actions per learning session, as well as the sequence of visited items.

The learner interactions are used to calculate the behavioural learning patterns categorised into three different levels ranging from 1 to 3, where 1 - low preferences, 2 - medium preferences, and 3 - high preferences.

4.1.3 Learner's brain dominance questionnaire

This study uses a questionnaire adapted from [30, 37] to identify the brain dominance and corresponding Learning Styles based on the investigated mappings between Learning Style and design features of WBES [23]. It was administered after verifying the validity and reliability of the items. Four experts from related disciplines (education, psychology and information technology) were consulted for the content and face validity of the questionnaire. The overall Cronbach's Alpha Coefficient was 0.812, indicating a high internal consistency [3].

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A Three point Likert scale, (1 = low preference, 2 = moderate preference and 3 = high preference) for the four Learning Styles (rational, organizational, interpersonal and intuitive) were identified to assess the learner's preferences towards the design features of a WBES.

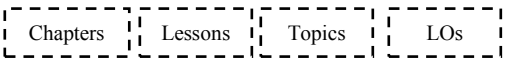
4.2 Participants

This work was carried out at the Faculty of Information Science and Technology (FTSM), National University of Malaysia (UKM). The study included 69 second year students who accepted the invitation to conduct the systematic observation study, and were using WEBS prototype effectively. All participants had experience in computing and web-based applications.

4.3 Place of Data Collection and Learning Tasks

4.3.1 Course structure and content

The location for conducting the systematic observation was identified to facilitate management of the data collection process [35]. The design features of WBES (e.g., the learning content features) developed according to HWBM LS, are the most important components in gathering the behavioural interactions in a WBES [38]. The study designed and organised a course module for the programming language, C++. Figure 3 presents the actual content structure for the learning content features in the WBES. The designed course consists of set of chapters; each chapter consists of set of lessons; each lesson contains set of topics; and each topic comprises of several different types of educational resources represented by Learning Objects (LO). A physical file represents each of these LOs and additional metadata describes the designed features, such as format, type, duration time, and educational roles. The description data was selected according to requirements for identifying HWBM Learning Styles. The total amount of developed and gathered LOs in this course was 337. Table 1 presents and categorises the LOs according to educational roles that match the requirements of the HWBM LS. This study developed an analysis tool to manage (add, update and delete) the LOs and metadata in the WBES. The presentation of learning objects in the WBES was designed especially to audit the learner's interactions with the content by linking each LO with a button, as depicted in Figure 4.



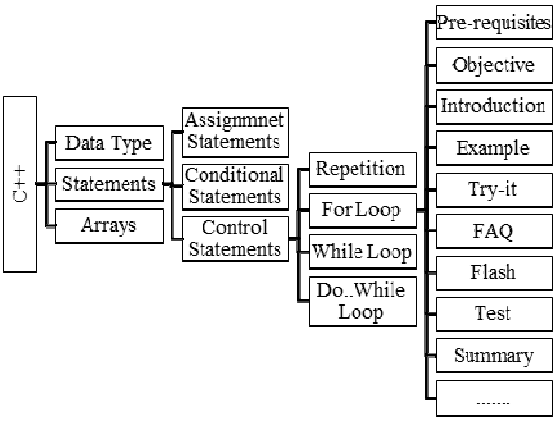


Figure 3: Organizing the Learning Contents of C++ Course

Table 1: Designing Learning Objects of Educational Roles according to HWBM (N=337)

Theoretical Learning Objects	Procedural Learning Objects	Practical Learning Objects	Interactive Learning Objects
Pre-requisite (5)	Sequential Slides Show (47)	Practical example (7)	Flash animation (16)
Problem (6)	Brochure (1)	Try it by yourself (12)	Flash cards (100)
Objective (5)	FAQ (6)	Example (15)	Syllabus (1)
Flowchart (14)	Lecture Notes (3)	Video tutorial (7)	Course outline (1)
References (3)	Exercise (12)	Group assignment(3)	Mind-map (1)
Open question(12)	Guideline (6)	Group project (3)	True/False question (18)
Individual assignment (3)	Pre-quiz (9)		Multiple choice question(18)
Individual project (3)			

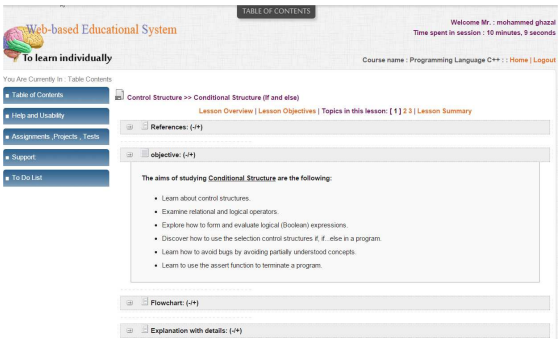


Figure 4: Presentation Interface of the Learning Content in WBES

4.3.2 Learning task design

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The learning tasks in the study were used to determine which parts of a system will be used to collect and evaluate data [34]. Additionally, in order to identify the learning preferences and Learning Styles of a learner from his/her interactions with the components of a WBES (e.g., help, learning content, problem solving, communication and support), and the appropriate learning tasks must be designed so that data collection can be managed without any bias in analysis [34, 36].

In this study, the participants were asked to engage in four learning tasks using the WBES prototype. As shown in Figure 5, the designed learning tasks focus on gathering the learner's interactions within the five different components of the WBES; each component provides different alternatives [24]. Questions i-iv addresses the learning tasks in this study. Figure 5 outlines the alternative solutions to these learning tasks.

i. What are the most preferred help methods for obtaining knowledge of new technology?
ii. What are the most preferred learning methods for studying a new topic?
iii. What are the most preferred methods for solving problems (assignments, projects and evaluation test)?
iv. What are the most preferred methods for solving challenging problems (assignments and projects)?
v. What are the most preferred channels for communicating ad collaborative with others to obtain support when facing challenges in problem solving?

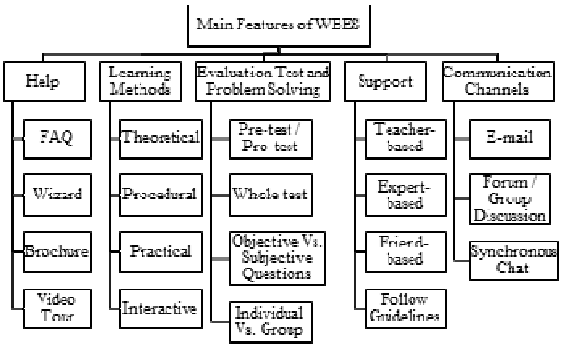

Figure 5: Alternatives Design Features of WBES for Learning Tasks

4.4 Procedure of Collecting and Analysing Data

4.4.1 Procedure of systematic observation study

Participants were first briefed about the system components and the objectives of the learning session. The learning session was conducted in four periods according to the designed learning tasks. For each learning task, the participants received a task sheet that contains the learning task description and its alternatives learning resources (i.e. WBES design features). The facilitator encouraged the learners to think and share their feelings of the preferred system features. Two hours were allocated to perform and accomplish all learning tasks in the WBES. The time given for each learning task was provided according to the nature of the activities.

The first learning task gathered behavioural interactions with the help feature and took 15-20 minutes. The second task, the main learning task, took about 40-45 minutes to gather learner's interactions when studying a new topic using diverse learning objects. The third task requires learners to solve two small projects (one is difficult) and two assignments (one is difficult) which took 30-35 minutes. The fourth task require learners to solve two exams, which took 15-20 minutes. Communication and collaboration tools were provided to support and help learners in solving challenges. Having accomplished these tasks, the participants were asked to answer the questionnaire so that their brain dominance could be measured.

4.4.2 Data analysis

SPSS version 20.0 was used to determine the Pearson correlation, a measure of the relationships between the behavioural learning patterns and learners' Learning Styles (determined from questionnaire). According to Saunders et al. [39], the correlation coefficient is appropriate to determine such relationships. Furthermore, according to Cohen [40], the correlation coefficient (r) of 0.1 depicts a small relation, a correlation coefficient (r) of 0.3 reflects moderate correlation and 0.5 (r) depicts a strong/high correlation [41].

5. RESULTS AND INTERPRETATIONS

Table 2 shows the results of the correlation test between the behavioural learning patterns (as measured by the WBES prototype) and learners' Learning Styles (as measured by questionnaire). The significant relationships and their implications on the recognition of the features for WBES design

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according to Learning Style of HWBM are detailed out in the following sections.

Table 2 Pearson Correlation Analysis (N=69, p<0.05)

Learning Style	Correlation Coefficient (r)	Learning Patterns
Rational Learner (QA)	.513**	n_askTeacherSupport
	.399**	n_askExpertSupport
	.398**	n_openQuestions
	.388**	t_FAQ
	.317**	t_objective
	.281*	h_objective
	.280*	h_references
	.271*	t_flowChart
	.255*	t_prerequisites
	-.255*	h_preQuiz
	-.253*	h_explanationWithDetails
Organizational Learner (QB)	.543**	n_guidelines
	.472**	h_slideShow
	.465**	t_preQuiz
	.407**	n_askExpertSupport
	.404**	n_askTeacherSupport
	.378**	t_wizard
	.335**	n_individualAssignment
	.311**	t_brochure
	.277*	n_openQuestions
Interpersonal Learner (QC)	.433**	n_askFriendSupport
	.416**	n_groupAssignment
	.400**	t_example
	.391**	t_tryit
	.360**	h_introduction
	.375**	h_tryit
	.358**	t_introduction
	.333**	n_forumComments
	.322**	t_videoTour
	.291*	t_forum
Intuitive Learner (QD)	.566**	t_flash
	.540**	t_overview
	.478**	n_multipleChoice
	.443**	t_mindMap
	.442**	n_feedBack
	.322**	n_askFriendSupport
	.304*	t_homePage
	.278*	h_outline
	.276*	h_syllabus
	.259*	t_summary
	.255*	t_tryit

5.1 Learning Patterns of Rational Learners

Table 2 indicates that the rational Learning Style significantly correlates with a set of behavioural learning patters at $p < 0.05$. These correlations are positive and negative, and ranged from small to high: t_Prerequisites (r=0.255), t_flowChart (r=0.271), h_References (r=0.280), and h_objective (r=0.281) (small and positive); t_objective (r=0.317), t_FAQ (r=0.388), n_OpenQuestions (r=0.398) and n_askExpertSupport (r=0.399) (moderate and positive); n_askTeacherSupport (r=0.513) (positive and high); and h_ExplanationWithDetails (r=-0.253), h_PreQuiz (r=-0.255) (negative and small).

Table 2 also shows that learner behaviours in the learning content design features (prerequisites, flowchart, references, objectives and details, help features (FAQ), support features (collaborate with teacher and expert), and evaluation feature (open question and pre-quiz) have significant effect on identifying the learning preferences for rational Learning Style. The findings also show that significant learner patterns include temporal behaviour with prerequisites, flowcharts, and FAQ features and navigation behaviour with references, objectives, open questions, communication channels with teachers and experts learning objects. Thus, it could be inferred that the rational learners tend to spend more time at reading and reviewing prerequisite topics and skills before studying a new topic. More time is also taken at logical thinking when viewing flowcharts. These learners tend to read the official help feature through reading the most common questions and its official answers. Furthermore, rational learners tend to navigate and browse official references such as books and articles to look for an intended topic/terminology/concept and prefer to open more communications channel with teachers and experts when facing challenges. In essence, it is found that rational learners adopt different WBES design features classified according to the main system components (Figure 6) as listed below:

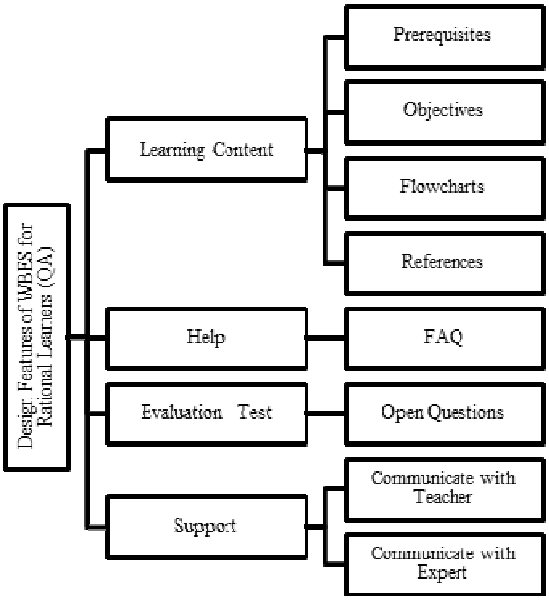

Figure 6: Observed Preferences of Rational Learners toward Design Features of the WBES

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1- **Learning content design features** (prerequisites, objectives, flowchart and references learning objects);
2- **Help and guidance features** (frequently ask questions (FAQ) to guide learners to know more details about new technology);
3- **Evaluation tests** (open question types); and
4- **Support features** (providing the learner with an online channel to ask teachers and experts obtaining help and support).

5.2 Learning Patterns of Organizational Learners

Table 2 indicates that the organizational Learning Style significantly correlates with a set of behavioural learning patterns at p<005. These correlations are positive, and ranged from small to high: n_OpenQuestions (r=0.277) (small and positive); t_Brochure (r=0.311), n_individualAssignment (r=0.335), t_Wizard (r=0.378), n_askTeacherSupport (r=0.404), n_askExpertSupport (r=0.407), t_PreQuiz (r=0.465), and h_SlideShow (r=0.472) (moderate and positive); and n_guidelines (r=0.543) (high and positive).

Table 2 also shows that learner behaviours in the help design features (brochure and wizard); learning content design feature (slideshow); problem solving and evaluation test features (pre-test, open questions, and individual assignment); and support features (guidelines and collaborate with teacher and expert) have a significant effect on determining the learning preferences of organizational Learning Style. The findings also show that the significant learning patterns consist of temporal behaviour with the brochure, wizard, and pre-quiz features and navigation behaviour with the guidelines, open questions, individual assignment, slide show, communication channels with teachers and experts features. Hence, it could be inferred that the organizational learners tend to spend more time discovering the new system by reading the brochure and using the automatic wizard to achieve learning tasks objectives. Also, they spend more time at testing their knowledge before studying a new topic. Furthermore, their navigation behaviour patterns reveal that organizational learners prefer to browse and navigate relevant features of these patterns when conducting their learning tasks. The results state that organizational learners tend to follow the guidance feature for all learning activities. For instance, they prefer using the slide show included with navigational guidance to help them go forward or backward sequentially. In essence, it is found that organizational learners adopt different WBES design features that are classified according to the main system components (Figure 7) listed as follows:

1- **Learning content** (slideshow);
2- **Help feature** (brochure and automatic wizard);
3- **Problem solving and evaluation test** (pre-test, open questions, and individual assignment); and
4- **Support** (guidelines and online channel to contact with teachers and experts).

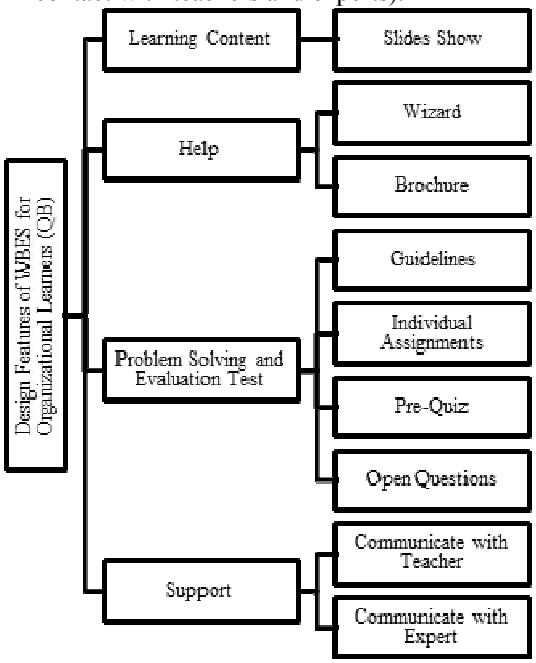

Figure 7: Observed Preferences of Organizational Learners toward Design Features of the WBES

5.3 Learning Patterns of Interpersonal Learners

Table 2 indicates that the interpersonal Learning Style significantly correlates with a set of behavioural learning patterns at p<0.05. These correlations are positive, and ranged from small to moderate: t_forum (r=0.255) (small and positive); t_videoTour (r=0.322), n_forum_comments (r=0.333), t_introduction (r=0.358), h_tryit (r=0.375), h_introduction (r=0.360), t_tryit (r=0.391), t_example (r=0.400), n_groupAssignment (r=0.416) and n_askFriendSupport (r=0.433) (moderate and positive).

Table 2 also shows that the learner behaviour with the help feature (video tour), learning content features (introduction, example, try-it by yourself),

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problem solving feature (group assignment), and support features (group discussion, communication channel with friend) have a significant effect on identifying the learning preferences of the interpersonal Learning Style. The findings also show that the significant learning patterns covered temporal behaviour with the introduction, example, try-it by yourself, video tour and group discussion features and navigation behaviour with the group assignments, try-it by yourself, introduction and communicate with friends features. This means that the interpersonal learners tend to spend more time and behavioural interactions (navigation) at the practical learning methods through reading/reviewing the examples and practicing what they are taught via special editors or simulation tools. Furthermore, the results show that interpersonal learners tend to watch videos that take a tour of the whole system component rather than read details/explanations. The group discussion to collaborate between friends and with each other is a significant feature that identifies the learning preferences of interpersonal learners. In essence, it is found that interpersonal learners adopt different WBES design features classified according to the main system components (Figure 8) listed as follows:

1. **Help design feature** (video tour);
2. **Learning content** (introduction, example and try it by yourself);
3. **Problem solving** (group assignment); and

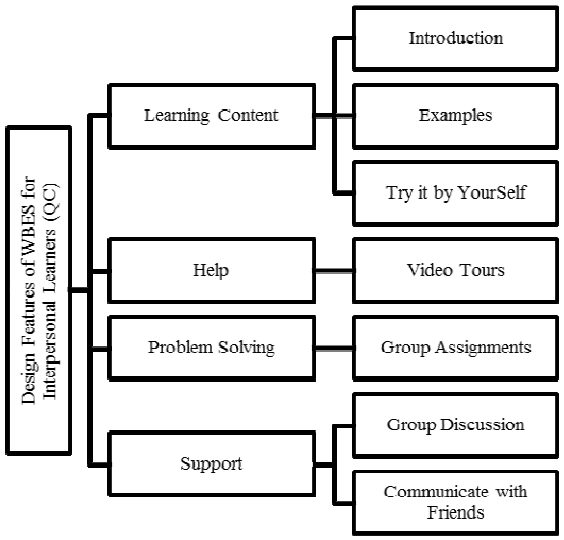

Figure 8: Observed Preferences of Interpersonal Learner toward Design Features of the WBES

4. **Support** (group communication channels such as forum and group discussion to facilitate the learner to collaborate with his/her friends to get support and help).

5.4 Learning Patterns of Intuitive Learners

Table 2 indicates that the intuitive Learning Style significantly correlates with a set of behavioural learning patterns, $p<0.05$. These correlations are positive and ranged from small to high: t_tryit (r=0.255), t_summary (r=0.259), h_Syllabus (r=0.276), and h_Outline (r= 0.278) (small and positive); t_homePage (r=0.304), n_askFriendSupport (r=0.322), n_feedBack (r=0.442), t_Mindmap(r=0.443), and n_MultipleChoice (r=0.478) (positive and moderate); and t_Overview (r=0.540) and t_flash (r=0.566) (positive and high).

Table 2 also shows that the learner behavioural interactions with the learning content design features (overview, flash and try-it by yourself), help features (mind-map and outline), evaluation test feature (multiple questions), and support features (ask friends and automatic feedback) have a significant effect on determining the learning preferences of interpersonal Learning Style. The findings also show that the significant learning patterns cover temporal behaviour with flash, overview, try-it by yourself, mind-map, and summary features and navigation behaviour with the multiple choice questions, feedback, and communicate with friends features. Thus, it could be inferred that the intuitive learners tend to spend more time at imagining overall components, internal interactions and procedures. Flash animation aims to visualize the procedure of executing the statements/instructions of program; mind map aims to visualize the overall components and its relationships in one place.

Furthermore, according to HWBM, the interpersonal learners tend solve the problems by thinking of alternatives in order to select the most accurate option. The results reveal that intuitive learners prefer to solve multiple-choice question types rather than open questions preferred by rational learners. Additionally, intuitive learners share some characteristics with interpersonal learners who prefer to discuss challenges with their friends rather than with experts and teachers. In essence, it is found that intuitive learners adopt different WBES design features classified according to the main system components (Figure 9) listed as follows:

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1. **Help design features** (mind map and syllabus);
2. **Learning content design features** (overview, outline, flash and summary);
3. **Evaluation test features** (multiple choice question types); and
4. **Support features** (ask friends for getting support and automatic feedback).

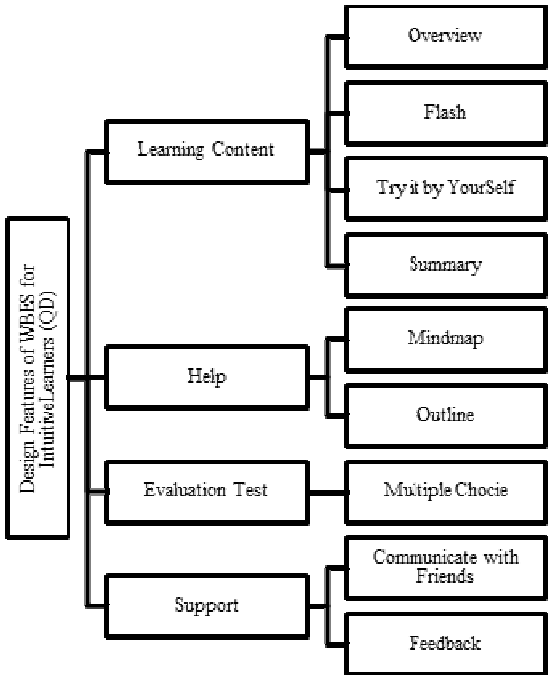

Figure 9: Observed Preferences of Intuitive Learners toward Design Features of the WBES

6. DISCUSSION

The results of this study provided the behavioural learning patterns, which reflect the observable learner preferences in WBES according to HWBM Learning Styles. Figure 10 presents the preferences model, which incorporates four main design features of WBES and their alternative options according to the Learning Styles of learners. These features interpret the aim of using HWBM LS to answer the question of how a learner likes to learn, communicate, collaborate, support and solve problems effectively. The main design features of the proposed model are learning content, collaborative channels to support learner, help and usability, and evaluation and problem solving. These features were used for tracking and analysing the behaviour of learner within WBES in order to infer learner brain dominance through identification of related learning preferences and Learning Styles. As depicted in Figure 10, the learning objects were proposed to accommodate the different requirements of learners according to their Learning Styles. For instance, rational learners tend to have more practice at reading objectives, prerequisites, flowcharts and references learning objects; organizational learners prefer and browse the learning content via slideshow learning object; interpersonal learners like to conduct their learning process by reading and interacting with introduction, example and simulation learning objects; and the intuitive learners like to integrate and visualise the learning contents by browsing the overview, summary and animation flash learning objects. Here, it can be concluded that the system, which covers the proposed requirements, is able to differentiate the learners' interactions and identify their learning preferences and Learning Styles effectively; and thus adaptation methods for adapting the different features of WBES is derived.

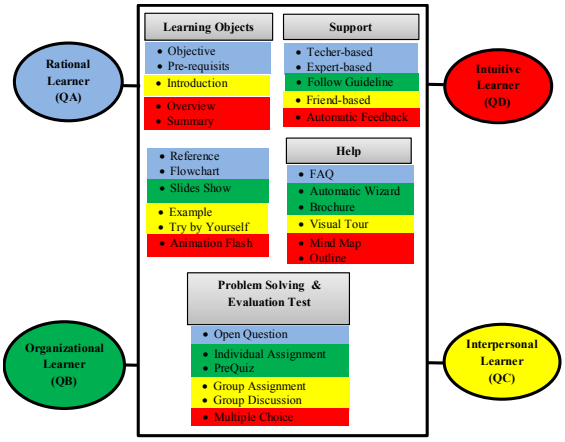

Figure 10: Observable Preferences Model for Learners in WBES According to Learning Styles

Results obtained thus confirm the investigated mappings between the Learning Style and design features of WBES in [23]. These mappings extracted the predefined learning patterns presented previously in Section 3. The results show that most of the behavioural learning patterns correlated to only one Learning Style. However, some learning patterns correlated to two Learning Styles such as (number of expert and teacher channels support, and number of open questions) correlate to two Learning Styles, were significant and related to both rational and organizational Learning Styles. These results are in line with how the brain structure operates; rational learners and organizational learners correspond to the left-brain thinking style, prefer to sequentially follow-up with instructions from expert, and like to read and write more than to think with alternatives when

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answering exams [9, 42]. Furthermore, the number of friend's support channels and time spent in the simulation environment were significant and related to both interpersonal and intuitive Learning Styles. These results are in line with operations of brain structure, interpersonal and intuitive learners correspond to right-brain thinking style, prefer to collaborate with friends and studying by trial and error (practical learning method) rather than reading the theoretical contents.

The results of the correlation test validate thirty six significant learning patterns, which correlate to the HWBM Learning Styles. These patterns allowed for the proposed observable preferences model for designing the WBES according to requirements of HWBM, as depicted in Figure 10. This model was proposed based on three research methods, including literature-based investigations, a validated questionnaire and a WBES prototype. Therefore, the proposed design features are reliable components that can be used to develop and implement an implicit approach for learner modelling [43].

7. CONCLUSION

This research investigated the postulates that every learner with different brain dominance has different behavioural interaction in the WBES. Significant relationships were found between the learner's brain dominance and his/her behavioural learning patterns based on the analysis of learner's interaction behaviours with the WBES according to predefined patterns.

Investigating these relationships is the first step towards proposing a novel approach of learner modelling to deduce the learner's brain dominance implicitly and automatically from the behaviour of learners in the system. The results provide a set of learning patterns to identify the learner's brain dominance in the context of WBES environment.

These patterns, which are used to relate the Learning Style with the design features of WBES, are limited to five system components. However, the user interface features such as (colour, navigation, content structure, accessibility, hyperlinks etc.) mapped with the Learning Styles [23] need to be investigated more to improve learner modelling by analysing the relationships between the learners' Learning Styles and their behavioural interactions on these features.

The learner modelling is the main issue for deriving the adaptation methods and rules to build and update the learner model; and thus develop an adaptive web-based educational system. Further research is needed to apply the current findings, which use a brain-based Learning Style model, for developing an automatic adaptivity for both of learner models and WBESs.

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Figure 2: Main Screen of the Web-Based Educational System

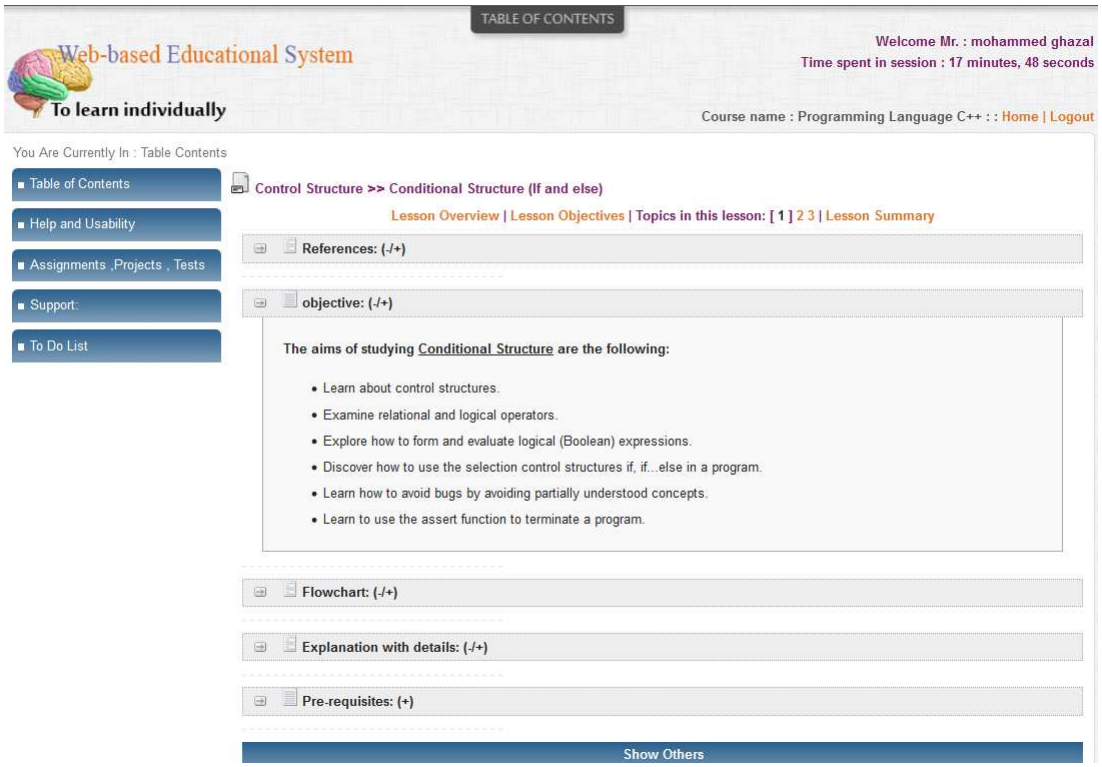

Figure 4: Presentation Interface of the Learning Content in WBES