International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-5, January 2020

Design of Cognitive MCQ test in Virtual Learning Systems to Determine Learner Affect

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Abstract: ***Virtual learning systems are expected to be adaptive to the grasp exhibited by the learner. Learner affects like confusion and confidence are displayed by the learner through behavioural cues. Identifying affect in a non-intrusive, sensor-free and scalable setting is preferable. Using interaction based behavioural log features; methodology for determining learner affect is presented. The MCQ test questions in the system are based on Bloom's Taxonomy Cognitive levels. The system records interactions of the learner. The regression analysis result on the dataset shows accuracy of confusion detection above 70%.***

Keywords: ***Cognitive levels, Virtual learning system, Learning affect, MCQ test, Interaction patterns.***

Abbreviation: MCQ: Multiple choice Questions.

I. INTRODUCTION

Virtual learning is preferred mode of learning and training. It is on demand, anytime type of system. The systems are designed for large number of learners. The contents are delivered in a push mechanism from the system but seem that system has less pull of leaner's actual grasp of learning contents. It is needed that systems adapt to learner's understanding level for personalization of contents.

We want systems which are adaptive to learning needs of the learner. Identifying learning affect is important part of adapting to the learning need. When learning systems are aware if the contents are understood by the learner, the systems can adapt to learner's needs. Sensor based approaches as presented in [2] have shown lot of promise in recognizing learner emotion. Systems are developed which capture facial expression of the learner while learning and interpret the emotion. Some systems are developed which capture brain activity to determine affect. [4] [10] [11] But for practical reasons, the sensor based approaches are costly and are intrusive in nature. Such systems are not easily scalable. They may impose a pressure on the learner of being monitored. It would be preferable to have non-intrusive, sensor free and scalable method to detect the learning affect. We present an approach for interaction pattern based affect detection. The system is designed to determine affect as learner attempts MCQ test.

Multiple choice questions (MCQ) examination is preferred assessment mode. In virtual learning system, MCQ type test assessment is automated. We need a system where not only assessment of MCQ is automated but understanding level of the learner is interpreted. [6] Research in [3] [4] have shown that learners exhibit their underlying learning affect while answering the test. The learning affects like confidence, confusion, frustration, satisfaction arise in the learner's mind depending on grasp of learning content.[12] Emotions experienced by the learner while learning and attempting the test. Learners express their emotions through their behavioural interactions with the system. Traditionally measurable learning outcome is correctness of answers in the examination. But, the performance in the examination is one of the factors of understanding. The learning affect can be indication of learning outcome. When affects like confidence, satisfaction are expressed after learning activity, we can propose firmly that the learning is effective. The affects like confusion and frustration imply learning episode is not so successful.

The learning system proposed in the paper is sensor-free, non-intrusive and scalable. The learner interactions with the system in terms of time, hint, and difficulty level are recorded in the system. The learning affect can be interpreted from such interaction features.

This paper presents a Bloom's taxonomy based approach for questions in the MCQ test. The MCQ test questions with associated cognitive levels are designed. Time, hint, number of clicks for choosing the option, pattern of attempt are various behavioural interactions of the learner while solving of the test. We establish correlation of the interactions of the learner with the learning affect.

A. Bloom's taxonomy Cognitive levels:

Bloom's taxonomy is a classification of learning behaviours [22]. We discuss cognitive domain here. The cognitive domain levels are used as foundation for affective learning system. Cognitive domain: It comprises of levels which depict knowledge acquisition and intellectual skill development of learner. It indicates the thinking and expression pattern of the learner based on level of knowledge learned. There are six levels in cognitive domain. The ordering from simplest to most complex level is: knowledge, comprehension, application, analysis, synthesis and evaluation [22], [28]. Each level is described in Table I.

Manuscript published on January 30, 2020.
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Table I: Cognitive Levels

Level Number	Cognitive Level	Description
1	Knowledge	It is ability to remember previously learned material.
2	Comprehension	It is ability to understand and comprehend the learned object.
3	Application	It is ability to apply the learned material in various situations.
4	Analysis	It is ability to decode the learned material for better understanding of its constituent parts
5	Synthesis	It is ability to construct the parts so as to formulate a new structure.
6	Evaluate	It is ability to judge the constructed structure so that a quantitative value is associated.

B. Affective states and learning affect:

Basic human emotions are anger, fear, joy, surprise and disgust [3]. More complex emotions and human nature characteristics are confusion, confidence, independence, flow, concentration and effort. These are affective states with respect to learning [21], [24].

Learning motivation is often recognized as the biggest emotion influencing the learning outcome [24]. In the context of virtual learning systems, confidence, confusion, independence and effort are found to be biggest contributor to learning gain. [27].

We define confusion and confidence of the learner.

Confusion is defined as lack of understanding and a state of uncertainty where learner is unable to decide how to act or what to do next.

Confidence is learner attribute observed through six factors studying, understanding, verbalizing, clarifying, attendance and grades.

II. METHODOLOGY

To determine affective state, virtual learning system which captures interaction parameters is required. The author has developed the online learning and examination system for second year computer engineering students for the course Data structures. The system records behavioural interactions of the learner.he system is designed in two modes: learning mode and examination mode. The methodology is depicted in the Figure 1

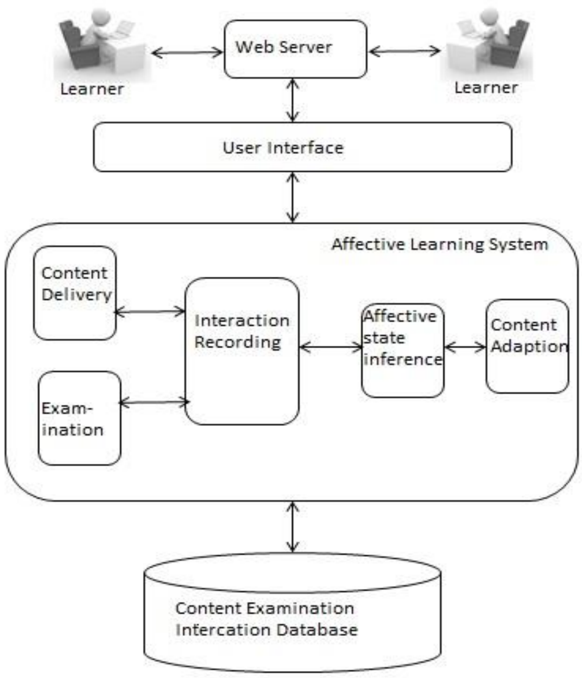


Figure1:Methodology

The learners attempt the MCQ test after learning activity of the topic. While formulating the questions of the test, the questions are ranked according to Bloom's taxonomy cognitive levels. When a student answers question of a particular cognition level correctly, we can interpret the understanding level of the student. When a student answers questions of knowledge level but cannot comprehend the answer it is definitely an indication of the lack of understanding. As cognition level increases, so level of understanding also increases.

Bloom's taxonomy based MCQ questions formulation:

The author has developed the MCQ test with Bloom's taxonomy cognitive level based questions. This section explains the approach for subject Data Structures if Computer Engineering branch. Data structures is a compulsory subject in Computer engineering Course at undergraduate level. Author feels the subject is universal to be able to express the method of associating MCQ test questions to cognitive levels.

The sample mapping of MCQ test questions to six cognitive levels in Bloom's taxonomy is explained in the following Table II which is in accordance to Bloom's taxonomy of education technology. [22]

Table II presents sample questions of subject Data structures of each cognitive level. Every question in a test can thus be associated with cognitive levels.

In the system designed by Author, MCQ test consist of 30 questions. All questions in the MCQ test are associated with six cognitive levels as explained in Table 2. The correct option selection by the student to solve the questions indicates the cognitive level achievement of the student for that particular question. The six cognitive levels are in the order of increasing difficulty.

Table II: Questions to Bloom's taxonomy cognitive levels

MCQ test Question	Options	Correct option (Answer)	Bloom's Taxonomy cognitive level	Justification
In a circular queue using array when front = rear +1 , indicates one of the following	a) queue is full b) queue is empty c) queue is half filled d) queue is almost full	a	Knowledge	Students are expected to know basic structure of circular queue to answer this question.
In a doubly linked list when you are inserting a node (in-between) after a given node, how many pointers need to be manipulated?	a) one b) four c) six d) zero	b	Comprehension	The students are supposed to remember insert operation and comprehend the answer
If an application requires entire process happening in a rotating manner, which of the following data structure will be preferred?	a) single linked list b) circular list c) array d) double linked list	c	Application	Students are required to apply knowledge of data structure to given problem
Which of the following is not a linear data structure	a) double linked list b) stack c) binary search tree d) double ended queue	c	Analysis	Students are expected to remember all structures pattern in options , then analyse and answer
typedef struct { int value; char name[5]; ELEMENT *next; } ELEMENT; This program code will be used for creating…	a) Double linked list b) File c) Single linked list d) None of above	c	Synthesis	Students are expected to read and compare data structure given properly where two data fields are given instead of expected convention of one data field.
Which of the following is true?	a) Postfix notations are do not require large memory space, hence they are preferred in computer systems b) Sometimes infix notations are implemented computer systems c) Generally Postfix notations are easy to remember, hence they are preferred in computer systems d) Generally postfix expressions are free from Operator Precedence that's why they are preferred in Computer system.	d	Evaluate	The students are expected to understand, compare and analyse all four options to evaluate correct option from all four options.

III. INTERACTION PATTERNS

There are other interaction patterns of the student with this virtual learning system. These interactions are in terms of time, hint usage, pattern of attempt, number of times answer options is changed before confirming the answer. We discuss these interactions.

1. Time: Time taken to solve each question in MCQ test. The ideal time per question is decided according to Bloom's taxonomy cognitive level of the question. The deviation from ideal time of the question is recorded.

2. Hint: Each MCQ question is provided with the hint. The help seeking behaviour with respect to cognitive level is recorded. Using hint at knowledge and comprehension level is expressing low understanding of the learner.

3. Clicks: The learner can answer the multiple choice questions by clicking one of the options. The system records the attempts of the learner in answering the question by tracking which options are submitted in every click for the question. The pattern in which the option gets chosen by the learner is logged.

4. Pattern of attempt (Sequence of answering the questions): In MCQ test, questions are packaged according to cognitive level of the question. So a test can comprise of number of questions of various cognitive levels. Questions of cognitive levels 1 or 2 can be easily attempted in the sequence provided by system. In case of higher level question, learner may jump over few questions. This is also an interaction pattern. The attempt of the student in answering questions as random or as per presented sequence is recorded.

5. Pattern of unattempt: The questions which are not attempted are maintained. For unattempt questions, clicks, usage of hint as well as time spent on the question, the difficulty level of the question is logged.

6. Correctness of answers: The system records the answers given by the learner and determines correctness of answer.

7. Wrong answers: The system records all interaction parameters for each wrong answer.

Here, MCQ test questions are in accordance to Bloom's taxonomy. The interaction patterns are recorded in the system dynamically as the test progresses for a student.

Table III shows a sample student's pattern of answering 30 questions of such MCQ test.

The table III shows the performance of a learner in MCQ test at various difficulty levels in terms of correctness of the answer as well as his/her subtle interactions with the system. The subtle interactions are expressed in terms of

i) Time: whether learner completes the test in time, before time or after time for cognitive level of the questions.

ii) Hint Usage: whether learner uses the hint provided and then answers correctly or answers correctly without using the hint.

iii) Clicks: whether learner clicks to confirm correct option in one go or changes mind number of times before confirming the answer.

iv) Pattern of attempt: whether the learner is confident enough to solve the questions in sequence or it hinders over because of unsureness of the answer to some questions.

All the interactions are associated with Bloom's taxonomy cognitive level questions as explained in Table 2. The combination of question level with behaviour of student (expressed in subtle interactions) conveys the underlying learning affect of the learner. They indicate learning confusion and learning confidence pertaining in students mind while attempting the test.

It can be interpreted that the student is very confident when higher cognitive level question is answered by the student correctly, before ideal question time, without using hint, with exactly one click per question and answer pattern is sequential.

We can state that student is confused when he could not answer correctly for lower cognitive level questions and takes more time than the ideal time for the question. The level of confusion can be interpreted to be very high when the student uses the hint and still answers wrong. It can be interpreted that clicking multiple options before finalizing the correct option. Similarly disorganised and jumbled manner of attempting the test is indicative of underlying confusion.

From the various interactions as discussed above we can establish a regression equation for prediction of learning affect.

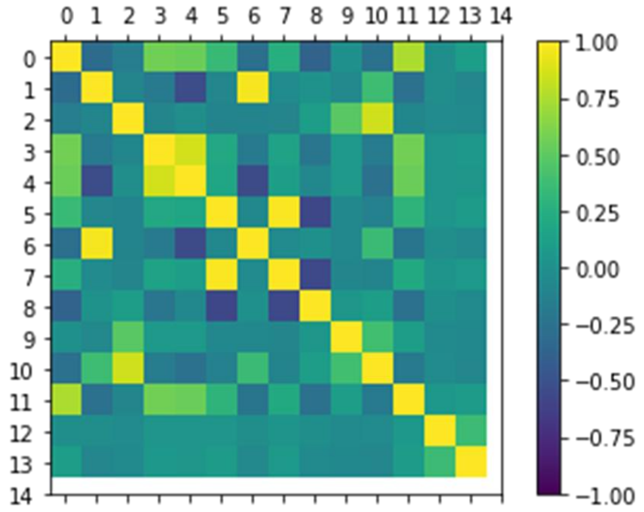
IV. EXPERIMENTAL RESULTS

The student interaction activity is captured for 150 students appearing for the test of data structures of second year computer engineering. The self-report of confusion and confidence while solving the test by students is recorded by the system. The self-report by students is in the range 0-9 where 0 indicates no confusion and 9 represents highest confusion.

The input features are the various behavioural interaction parameters captured by the system as well as the performance of the student in the test for all types of cognitive level questions. It is recorded in the system.

We performed correlation analysis to see if there is a correlation between input features. Figure 2 indicates correlation matrix heat map. The first 14 features indicate that the correlation between the features is not linear. Correlation values are in the range -0.5 to 0.5. It confirms non-linearity between the input feature variables.

Figure 2. Correlation Heat map of input features



For the captured dataset of the students, we implemented multi-variate linear regression in Python programming environment.

$Y = \beta 0 + \beta 1.x1 + \beta 2.x2 + ... + \beta n.xn$ (1)

Where,

Y is target variable. The learning affect confusion is target variable.

Independent variables x1….xn are interaction features like time, hint usage, pattern, clicks that are captured in the system.

$\beta 0 .... \beta n$ are multiplication factors.

We perform 10 cross-validation on the dataset so that bias and variance is taken care of. The application of multivariate regression equation as given in (1), to the learner interaction dataset produced promising result.

The overall efficiency of confusion detection achieved is 75.31%.

The confusion matrix is presented in Table IV. From the true negatives value in confusion matrix, we can say that the system predicts no-confusion with above 90% accuracy. From true positive values, we can say that presence of confusion is achieved with above 65% accuracy. The inherent human bias can be the reason for the same. The results can be improved as system gets trained on bigger dataset.

Thus we can say that, the system is able to determine learner confusion using cognitive level based MCQ system in virtual learning.

Retrieval Number: E6549018520/2020©BEIESP
DOI:10.35940/ijrte.E6549.018520
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table 3: Sample interaction patterns of a student

Sr No	Questions' Cognitive Level	Student Interaction Activity while attempting test				
	Total Questions in MCQ test: 30 Number of Cognitive levels: 06 Number of questions of each cognitive level: 05	Correct Answer Corr_ans, wrong_ans	Answered Time before time, in Time, after Time Ans_before Ans_in Ans_after	Hint usage (yes/no) Hint_used Hint_not_used	Number of clicks for 5 questions of the cognitive level No_ of_Clicks	Pattern of attempt (sequential, non-sequential) attempt_pattern
1	Knowledge	Yes (2) No(3)	Before(2) In(2) After(1)	Yes (2) No(3)	12	Sequential
2	Comprehension	Yes(1)No(4)	Before(1) In(1) After(3)	Yes (1) No(4)	15	Non-sequential
3	Application	Yes(3) No(2)	Before(2) In(1) After(2)	Yes (1) No(4)	5	Sequential
4	Analysis	Yes(3) No(2)	Before(3) In(1) After(1)	Yes (2) No(3)	4	Non-sequential
5	Synthesis	Yes(4) No(1)	Before(1) In(3) After(1)	Yes (3) No(2)	15	Non-sequential
6	Evaluation	Yes(1) No(4)	Before(0) In(2) After(3)	Yes (2) No(3)	14	Sequential

Table IV: Confusion matrix for affect detection

N= 150	Predicted No	Predicted Yes
Actual No	46	03
Actual Yes	35	66

V. CONCLUSION

The adaptive learning system design is based on cognitive level MCQ test. The system maintains the interactions of the learner so that cognition level of the learner can be interpreted. The main objective of the system design is to determine learning affect confusion and confidence. The system determines not only correctness of the answers but also determines the grasp of the learnt contents.

Multi-variate linear Regression analysis determines the learning affect with 75.31 % accuracy. We can confidently interpret that behavioural interaction parameters are indicators of learning affect of the learner. The methodology is non-intrusive, hence the pressure of being monitored does not exist on the learner. The subtle, natural interactions of the learner with the virtual learning system are captured as the MCQ test proceeds. The system can interpret the learning confusion and confidence of the student. Such systems can be used as adaptive learning systems which adapt as per the learning affect.

When confusion is determined the system can repost the learning content to the learner. When confidence is determined, the system can speed up the content delivery process or enable such learner for learning more advanced topics. This can bring virtual learning experience near to classroom learning experience for the learner.

ACKNOWLEDGEMENT:

The authors would like to thank the management of K J Somaiya College of Engineering, Vidyavihar, Mumbai for allowing to conduct the above experiment with students of Computer Engineering

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