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A Teaching-Learning Model for Software Engineering Courses through Sensor-Based Cognitive Approach*

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There is a big revolution and discussion regarding the education system of the students pursuing engineering education in highly populated countries. Educating Engineers is a highly motivating as well as a challenging task. However, the students from diverse environment perceive the lecturing of the Teachers at different levels. This paper discusses the importance of student's preference in initiating a cognitive based learning environment for engineering education. This includes the evolution in reversing the teaching mode for industrial perspective courses such as the "System Analysis and Design" course which is pursued by students across various engineering disciplines. Similarly, Software Engineering relates to analyzing and building software systems. Object-Oriented Analysis & Design focuses on the analysis and design of software systems as related objects. A Coordinated Cognitive Thinking (CCT) model to evaluate the cognitive behavior of the students has been proposed so as to analyze the requirements of the students towards Software Engineering related courses. The need for cognitive based learning is assessed through Need For Cognition (NFC) scale with the focus on software system analysis and development. The response is evaluated through wearable sensor technology. Experimental results of around 70 students pursuing the Object-Oriented Analysis course have been taken into consideration. The results obtained revealed the fact that there should be a renaissance in engineering education by continuously reviving the teaching methodology for engineering students.

Keywords: cognitive thinking; teaching-learning process; wearable sensors; object-oriented analysis & design; software engineering; system analysis and design

1. Introduction

The Teaching-Learning model provides a framework that enhances the Teaching-Learning Process (TLP) through cognitive approach. TLP is a complex process involving Teachers and students with different levels of perception, knowledge, age, behavior, motivation etc, has to work together. The focus of the student is the thirst for knowledge and the focus of the Teacher is to impart knowledge which stimulates the student's thirst to greater heights. Within the stipulated duration, it is near impossible for the Teachers to meet the expectation of individual student. Piaget [1] and other theorists emphasized that "The essence of learning is that to teach the learners, how to apply the cognitive pattern what they have already developed to the new content". The identification of the cognitive skills of the students is a major challenge to the Teachers. In particular, students with different engineering focused design instruction [2] acquire different cognitive skills which can be used in enhancing the problem solving and decision making skills.

According to Richard M. Felder and Rebecca Brent [3], the instructors (Teacher) should support a teaching approach that promotes the intellectual ability of the students. This constitutes the following five features:

- There should be variety in the tasks assigned and the choices should be provided to the students at all levels.
- Instructors should explicitly communicate and explain their expectations from the students clearly.
- For high-level tasks, the instructor should model and practice the tasks such that the students are familiarized with the task.
- A student centered instructional environment should involve active learning and cooperative learning. Active learning partially replaces the lectures with course related activities. In cooperative learning, the students work in teams to complete a task.
- Instructor should possess a positive attitude towards the development of students at all level with respect and care.

These features and especially the learning approach with which the proposed work is concerned have helped the students in acquiring their skills and improve their level of thinking. The aim of this paper is to enhance TLP and to enable the students to be an active participant of this process. A Coordinated Cognitive Thinking (CCT) model has been proposed to identify whether the students are motivated towards cognitive based learning. Context based learning [4] helps in adopting the

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product, process and system lifecycle as the context for engineering education. Context based learning derives its root from cognitive based learning. Therefore, cognitive based learning is a proven gateway for system development courses in engineering disciplines. These courses apart from conceptualization are capable of motivating the thinking capability of the students.

In order to identify whether the students are interested towards cognitive based learning, the students are made to undergo a series of Need For Cognition (NFC) questionnaire [5]. The pre-status of the students is analyzed through a Pre-Behavioral Cognitive Thinking Detection Technique. There are other cognitive assessments which discuss the overall characteristics of the students. Bloom's taxonomy [6] focused on six major categories in the cognitive domain that was widely used in classifying curriculum objectives apart from other applications. Ivan S. Gibson [7] has observed that the education of engineers, from the European perspective, is changing from the chalk and talk approach to the project/problem based activities approach. The logical thinking [8] and the performance of students [9] have also been assessed through cognitive skills of individuals as well as groups. However, the proposed approach is a novel model which investigates whether in educating engineers, there is a need for cognitive based learning specifically for courses related to system development.

The Conceive-Design-Implement-Operate (CDIO) approach [10] is a major challenge in educating engineers for developing complex value added systems in a team-based environment. Cognitive based approach facilitates the interest of the students especially in complex system development across various engineering disciplines. The product that is to be engineered and the process that provides a framework for the engineering technology [11] is the foundation for Software Engineering related courses. Computer Software is the product that Software Engineers design and build. Software Engineers build it and everyone in the Industry uses it either directly or indirectly. An Object-Oriented approach is an iterative and evolutionary approach from the classical software development approach. The system to be developed follows the similar Analysis-Design-Implement-Maintenance approach.

For analyzing the cognitive behavior of the students, around 70 students were requested to respond for the NFC questionnaire. This was implemented only after detecting their pre-behavioral pattern. The students were requested to view the questionnaire as related to development of the system using Object-Oriented approach. The questions have been categorized accordingly which has been given in Appendix I. Since the number of students in each batch is relatively higher, it becomes an impossible task to analyze the cognitive behavior of the students individually. However the need for cognitive thinking is an essential component for System Analysis and Design courses. This is due to the fact that the TLP for these courses always tend to be a one-way communication where the Teacher teaches and the students listen. This forces the student to create subtle interest in these subjects. In order to break this trend, the TLP should be of a two-way communication. However, such initiation by the Teachers always end up with a very few students responding back irrespective of a larger number of students capable of initiating the interaction. To make the session an active teaching learning session, the CCT model through wearable sensors has been proposed. This motivates both the students and Teachers in making the lecturing session into an interactive session with an active participation of a major number of students.

Recent research [12] have explored other areas which are sub classified from Wireless Sensor Networks (WSN) such as the Wearable Sensor Networks, Body Sensor Networks, ubiquitous computing etc for specific applications such as surveillance, education and health monitoring. The behavior of the students is analyzed through wearable sensor enabled devices. These sensor nodes are grouped into a cluster and the Teacher acts as the Cluster Head (CH). The response from the student is processed and the resultant analysis is forwarded to the CH (Instructor node). A detection scheme has been formulated so as to determine the pre-behavioral impact on the student's cognitive behavior. The CH node depending upon the response will shift the lecture session to an Interactive Thinking-Learning session accordingly. The aggregated response from the students will facilitate the Teacher either to proceed towards conceptual mode learning or to switch to cognitive mode learning.

An innovative CCT model to enhance the TLP has been proposed. Initially, the students are requested to respond to a NFC series of questions. The NFC series have been carefully designed so as to shift the focus to system development using Object-Oriented approach. The response of the students is received by the Teacher through wearable sensor technology. The response is analyzed through a Pre-Behavioral Cognitive Thinking Detection technique. The students irrespective of their performance score have responded positively which highlights the need for cognitive based learning for System Analysis and Development related courses, in particular for engineering education. The results reveal the fact that students are shifting their focus from traditional lecturing system and moving towards cognitive based learning system.

2. Related work

The study of the relationship between student's perception and the Teacher's observation is always a promising field since this provides an insight into the manner the engineering education system should evolve. This section deals with the recent research that has been emerging in TLP and the impact of the cognitive based learning in a detailed manner.

Cacioppo et al. [5] introduced the NFC scale to indicate that the high scorers engage in thinking about topics as they are presented, enjoy the thinking process and are motivated to apply their thinking skills with little prompting. Such people are likely to be able to process and systematize information, sorting out the irrelevant from the important. These people enjoy experiencing new challenges with deep affinity in their effort to achieve the required goal. This scale helps in understanding the behavior of the students in the classroom learning process.

Ana-Maria Cazan and Simona Elena Indreica [13] explored the relationship between the need for cognition and the various approaches to learning. Their research has revealed that the need for cognition scale is a reliable measure and the students with high cognitive measure involve in critical thinking activities more effectively. This motivates the proposed work to measure the student's cognitive thinking capability through NFC scale.

Godfrey et al. [14] suggested that the learning process of Engineers should be modified to achieve competence rather than gaining subject knowledge of the system to be developed. This can be achieved by making the students to identify the challenges of the system, design the framework of the system, the measurements required and finally to analyze the performance of the system. These findings further motivate the fact that a unique approach is required in educating engineers in systems thinking, design and implementation.

Heijne-Penninga et al. [15] examined the relationship between deep learning, need for cognition and preparation time. Also how it impacts the score in the open and closed book test. These studies reveal interesting factor that the students with cognitive skills scored high in both open and closed book components. This again emphasize that learning should impart the knowledge required for their specific disciplines which is well acquired through cognitive-based learning.

Tahira Anwar Lashari et al. [16] argued that an integrated positive behavioral engagement will induce more active participation of students in moving towards an effective teaching learning process. This study explores the need for the capability extraction of the students depending upon their cognitive and affective behavior which will motivate towards a positive engagement of the students in their academics. However, the individual behavior of the students and their cognitive skills has not been taken into consideration.

Roose et al. [17] have studied the temperament of youth with respect to reactive and self-regulatory features. The youths either suppress their behavior or try to exhibit their emotions. These may either result in a productive or counterproductive manner depending upon the individual's social or economic background. The proposed work takes into account the characteristics of the students (youth) in order to measure their motivation towards the critical thinking process. Chyung et al. [18] designed a pre-instructional e-learning strategy which stresses the Improvement of Engineering student's cognitive and affective preparedness for classroom learning. However, the behavior of the students with respect to their classroom learning has not been taken into consideration.

Petropoulakis and Flood [19] developed an interactive classroom engagement system using wireless hand-held pocket devices. One of the motivations towards the development of such a system is to evaluate the response of the students pursuing engineering courses. However such systems do not assess the cognitive thinking of the students such that there can be an evolution from the traditional lecturing format. This is the need of the hour since there is a tremendous shift in the attention span of the students.

Joonas Westlin and Teemu H. Laine [20] discussed the need of context aware applications for wearable sensors which can be inferred with the relevant data access mechanisms. These nodes are implemented in various contexts such as health sector, military sector etc. . . Due to the distributed behavior, these wearable sensors can be used for other context oriented mini-applications also. These wearable sensors can be used as a medium through which the critical thinking capability of the students can be assessed accurately and further decisions can be made appropriately.

Robert Mathews et al. [21] explored the state of the art body-worn system that can be used for real-time monitoring of the subject's physiology and cognitive status. These applications can vary from military personnel monitoring to patients monitoring. Depending upon the applications concerned, the physiological sensor suite can be tuned to capture the data pattern. The collected data can be used in determining the cognitive state of the individual focusing on the application concerned.

Okeyo et al. [22] discussed the challenges in real time activity recognition through data segmentation. From the state of the activity of the subject and the temporal information, a dynamic segmentation model has been proposed to improve the accuracy of the activity sensed. The characteristics of a wide range of activity which will vary depending upon the context have been analyzed. Juan Ye et al. [23] presented an unsupervised technique that combines data sensed and the knowledge gathered from the data. The domain knowledge gained can be reused for a wide range of users and their activities in a diverse environment. The data received from the sensors can be used to analyze the pattern of user's activities depending upon the environment. From these works, it is observed that the individual's cognitive behavior depending upon the application can be sampled through wearable sensors.

This study facilitates the need for cognition and its effect on the teaching as well as the learning process and how wearable devices can help us in understanding the cognitive behavior of the individuals. The following section deals with the techniques involved in coordinating the TLP.

3. Methodology

This section elaborates the proposed Teaching-Learning model, CCT in a detailed manner. In order to effectively execute the CCT model, the pre-behavioral description of the students is detected. This is made possible by developing a cluster formulation of the students with the Teacher as the Cluster Head (CH) using wearable sensor technology. The first section deals with the cluster formulation of the Teacher and the students. After the formation, the following sections deal with the evaluation of the critical thinking capability of the students. If the investigation is positive, the NFC questionnaire is provided to the students with the focus on Software Engineering related Courses i.e. Object-Oriented Analysis and Design. The results of the questionnaire help to understand the student's affinity towards cognitive based learning.

3.1 Teaching-learning process (TLP) formulation

The Teaching Learning Process (TLP) is a continuous cognitive process which evolves across time. This process is a learning process not only from the student's perspective but also from the Teacher's perspective too. The TLP enriches both the students and the Teacher which further nurtures the ultimate goal of education. In this process, the Teacher may not always adhere to the traditional lecturing process instead may explore some other means of education so as to meet the student's expectations. On the other hand, the students who are caught within the gadget encapsulated world anticipate other form of TLP apart from the continuous lectures.

The sensor nodes are the student nodes which generates the required data that induces the transition in the TLP. In such a scenario, the students who undertake a particular course are considered to be one cluster and the Teacher is elected as the CH.

For any Group $G = (V_i, E_{ij})$, where
$i = 1, 2, 3, ...n,$
$j = 1, 2, ...n - 1$ such that

$$G_s = \begin{Bmatrix} 0 & t <= 0 \\ 1 & t > 0 \end{Bmatrix}$$

where G—student cluster,
V_i —student node in the i^{th} position
E_{ij}—the path between the student node i to j
G_s—state of the Group G
t—time at which the Group is in active mode

At time t = 0, the nodes form the network and the CH of the node is elected with reference to the time period. The data generated by the node are forwarded to the other nodes until it reaches the CH for further analysis. This analysis will impact the TLP process which leads to an adaptive evolution towards the transition in the teaching methodology. The cluster will be in the active mode for the scheduled time interval and after the completion of the scheduled time "n" will switch back to sleep mode. This is illustrated in the Fig. 1. At time t= 0, the nodes are in sleep mode.

At time t = 1, the group G initiate their communication with CH node. Initially the nodes are in the inactive mode. At time t > = 1, the Teacher initiates the teaching process. The cluster formulation is processed. At anytime $t \leq n$, the NFS questionnaire can be triggered and based upon the response, the TLP can be switched to a lecturing mode or an interactive mode.

3.2 Learning-thinking stimulation process using wearable sensor network

Data collecting process for rigorous analysis has become the need of the hour. In a class room students information need to be collected, in an organization employees information need to be collected, in a hospital patients sensitive information need to be collected, in homes, children status information need to be collected and the list is endless. With wearable sensors, the process of collecting data has become even more flexible since the sensor can be any wearable tiny device without causing any inconvenience to the individuals under observation. Since the sensor nodes are

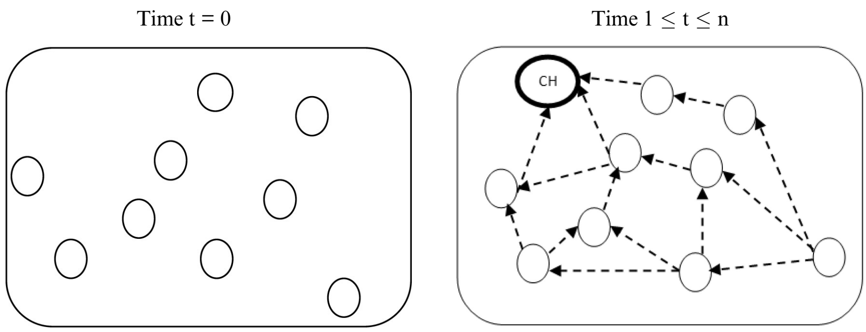

Fig. 1. Cluster Formation.

Table 1. Impact of pre-session activities

Scale	Previous-sessions	Weight (w) (numbers / levels not exceeding 4)
1	Continuous lecturing sessions	25 (× number of Hours)
2	Assignment submissions due	20 (× number of Assignments)
3	Pre-requisite content knowledge	15 (× number of Hours attended)
4	No class	10 (× number of Hours)
5	Socio-economic status	5 (× levels of peer pressure)

application-centric, the generated data can be processed with the précised specifications.

After the cluster formulation, the initial constraints of the nodes are observed with reference to the preparatory level of the students. The pre-learning thinking process of the students is examined with the following scale of reference as shown in Table 1. This is concerned with the previous session's impact on the critical thinking capability of the students. As per the discussion with the students, it has been observed that the thinking process is inspired with respect to the other factors that are directly or indirectly related with the academic activities. If the previous classroom sessions were continuous lecturing sessions irrespective of the diverse subjects, it has a severe impact on the cognitive behavior of students. If there were any assignments (may include seminars, presentation etc. . .) submission due for other subjects and hence the student's concentration may be diverted.

Another factor to be concerned is the pre-requisite knowledge required for the course. Only with such requirement specification, the students may be able to apply their cognitive skills. If the previous sessions were free (no classes) sessions, this may create a converse effect depending upon the number of hours in idle state. Therefore the effect of free sessions is calculated with respect to the number of hours that the students were idle. In this context, the term "idle" refers to the status of the students who are not involved in any academic related activity. The socio-economic status of the students also affects the student's motivation towards the thinking process.

With this scale taken into consideration, the level of cognitive behavior of the student for the subject to be handled is examined. The pseudo code for cognitive thinking initiation process with respect to the scaling factor is formulated as below.

```
Pseudocode : Pre-Behavioral Cognitive Thinking
Detection
begin
  Initialize stud_mode_count [4] to zero for all
  the 5 modes
  For given N number of students
    begin
      switch scale // scale referred from Table.1
        case 1 : sleep mode;
        case 2 : busy mode;
        case 3 : super active mode;
        case 4 : active mode;
        case 5 : inactive mode;
        compute stud_mode_count;
      end
        find maximum of stud_mode_count;
        if (max_stud_mode_count is active and
           super active)
          Start the NFC questionnaire;
        else
          exit;
  end
```

The switching mode of the students is identified taking into consideration the scaling factor with number/levels = 4 as shown in Table 2. The weights have been defined for the scale that is illustrated in Table 1.

If there is a continuous 4 hours lecturing session, the students tend to be in sleep mode which may heavily affect their cognitive feature. If there are assignment dues, the students will be busy focused in submission of the assignments. If there is a

Table 2. Mode computation

Scale	Weight (w) (numbers / levels not exceeding 4)	Mode
1	25 (× 4) = 100	Sleep
2	20 (× 4) =80	Busy
3	15 (× 4) = 60	Super active
4	10 (× 4)= 40	Active
5	5 (× 4) = 20	Inactive

profound knowledge in the respective score, the students will be interested in critical thinking activity. The socio-economic status of the students will also reflect in their critical thinking capability. If the student's preparatory level implies maximum count in the active and super active mode, the students are requested to respond for the cognitive skill based questionnaire. This is elaborated in the next section.

3.3 Need for cognitive skills in engineering education

Educating Engineers is concerned with imparting knowledge to the students in designing, building, maintaining and innovating structures. Although the focus remains the same, the structures may vary with respect to the engineering discipline. This knowledge transition is made possible only if the students are engaged in critical thinking, which motivates to analyze the system and reinvent the system taken into consideration. In order to find out whether the students are intended towards cognitive based learning, the Need For Cognition (NFC) scale is introduced. The questionnaire consists of a series of 18 questions from (NFC) Test [5] which is specified in Appendix I.

These questions were restructured so as to be more specific with respect to the system analysis, design, implementation and testing using Object-Oriented approach. Similar observations can be made for other approaches. The scale "Extremely Uncharacteristic" indicates the individual's strong disagreement to the given statement. Also, "Extremely Characteristic" specifies the student's strong agreement with the statement. The students responded to this 5-point scale. Some statements are contradicted and for these statements a reverse score is calculated.

The Analysis phase investigates the requirement of the system where the large complex system has to be categorized into related subsystems. It requires many brainstorming sessions until the requirements are clearly defined. This has been the focus of the analysis based questionnaire. The Design phase realizes the integration of the actual components as identified in the analysis phase. This requires a lot of critical thinking which is the focus of the questions categorized in the Design inspired questions. After designing, the execution of the design is the core of the implementation phase. Some reverse score questions have been specified which makes the students to identify the implementation aspect of the system. For example, "Thinking is not my idea of fun" statement makes the students to examine whether cognitive thinking is required at the implementation phase of the system. The maintenance related questions scrutinizes the students way of thinking towards providing required support to the system that has been developed.

The NFC scale is a combination of multiple items where each individual item measures the cognitive skills of the students quantitatively. The attitude of the students depending upon their perception can be from "Extremely Uncharacteristic" to "Extremely Characteristic". Each Item in the scale is a statement which has several response choices. The students rate according to the response that reflects their attitude with reference to the system development. The internal consistency of the scale is measured using Cronbach's alpha technique. Cronbach's alpha [24] is a test reliability technique that requires only a single test administration to provide a unique estimate of the reliability for a given test. The item output analysis has been depicted in Table 3.

In the Table 3, the Item Means is the summary statistics for the eighteen individual item means. The Item Variances is the summary statistics for the eighteen individual item variances. The Inter-Item Correlations characterize the correlation of each item with the sum of all remaining items. Similar computations have been made for the 18 items. An alpha of 0.86472 is probably a reasonable goal. It should be noted that a high value for Cronbach's alpha indicates good internal consistency of the items in the scale. The internal consistency of the items establishes the fact that the NFC scale can be used to measure the need for cognitive based learning for system development related courses.

Table 3. Item Output Analysis

Item (N=18)	Mean	Minimum	Maximum	Range	Max/Min	Variance
Item Means	11.8	11.4	12	0.6	1.05	0.02353
Inter-Item Correlations	0.68083	0.39793	0.97218	0.57425	2.443	0.03973
Cronbach's alpha Reliability coefficient				0.86472		

3.4 Coordinated cognitive thinking (CCT) for SEOC

For Software Engineering Oriented Courses (SEOC), it is essential that students are actively involved in each and every aspect of the subject. Henceforth, the lecturing sessions of these courses cannot be of one-way communication where the Teacher lectures and the student listens. These sessions should be of interactive in nature where the Teacher builds the concept and the student applies the concept to develop the software systems. This application of concepts to a complex system may acquire additional thinking skills which may not be exhibited by the students in an academic environment. The expertise of the students can be analyzed through a Cognitive series test exclusively from the Software Engineering perception.

The formulation of the NFC questionnaire for SEOC was developed as referred in Appendix II so as to make the students to response with reference to SEOC. The aim is to understand the need of the students who are pursuing SEOC. The questionnaire has been formulated such that the analysis, design, implementation and maintenance of a system are taken into consideration. The questions are classified with reference to these phases. In the analysis phase, the questions focused on the components such as the need for analytical thinking, passion towards incremental thinking, focus towards long-term goals and improving thinking ability so as to analyze the system to the core. In the design questionnaire section, the questions were elaborated on the need for high-level design, critical thinking towards a system, innovative designs and the need for abstract thinking which helps in designing the system to work efficiently in real-time. The implementation questionnaire section elaborates the satisfactory level of individual such that their intellectual thinking capability has proven to be right or wrong personally. The maintenance questionnaire section includes the evolutionary thinking that will support their evolutionary way of approaching the SEOC.

The CCT is formulated as below:

```
Pseudo code:
start
     Step 1: Determine the period of classroom
             session
     Step 2: Start the initial process
     Step 3: Identify the CH and the
             corresponding nodes for the
             Current session
     Step 4: Individual nodes respond to the
             Cognitive Thinking series.
     Step 5: Generated Data (response)
             forwarded to the CH
     Step 6: Compute the score for the NFC.
     Step 7: If the score is relatively higher,
             Interactive-Thinking-learning
             process evolves
           else  continue; //lecture mode
end
```

In order to cater to different types of learners where the TLP should be of a two-way communication, an effective mechanism for the involvement of the students can be through the SEOC based NFC questionnaire series. The learners may hesitate to give their direct response to the Teacher which may have a counter reaction. Instead through the wearable sensors the students may be able to give their response towards the learning and thinking process. This response aggregated may facilitate the Teacher to motivate the thinking capability of the student.

The feedback from the students may help the Teacher to switch from the lecturing session to the brainstorming session. For such an initiative to be accomplished, the cognitive thinking of the students towards the subject is resolved through SEOC based NFC. An 18 item questions are made open to the students and the response is triggered back to the Teacher who is the CH. After receiving the response, the scores are computed and depending upon the scores as referred from Table 2, the thinking learning process is initiated. The initial process involves the identification of the group and their corresponding CH. The response from the students is received by the CH. The scores are computed and depending upon the scores, the Interactive-Thinking mode is initiated.

4. Results and discussion

An initiative towards cognitive based learning has been modeled for SEOC. This is accomplished only after reviewing the underlying issues involved in pursuing these courses. Around 70 students of different batches who were pursuing Object-Oriented Analysis and Design subject were taken into consideration. These students were provided with the NFC questionnaire and the average response time was calculated. The questionnaire was segregated with respect to the Object-Oriented analysis, design, implementation and maintenance phases. The students were requested to provide their feedback from this perception. The results were quiet interesting as the students response towards cognitive based thinking was highly positive irrespective of their individual scores in the subject.

The preference of students for the analysis phase has been illustrated in Fig. 2. From the NFC questionnaire, the questions relevant to the need of thinking in the system analysis phase have been examined. The questionnaire scale includes analytical, incremental need for improving the thinking

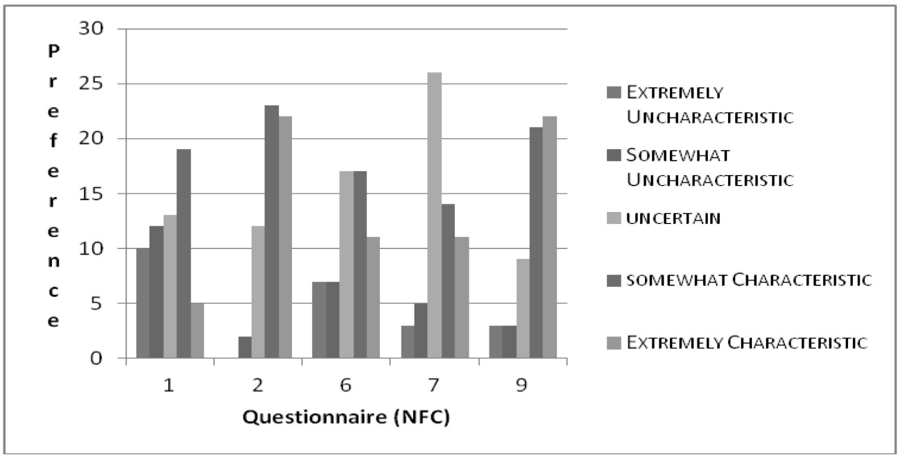

Fig. 2. Object-Oriented Analysis inspired Questionnaire.

capability and the ability to achieve long-term goals from the student's perspective.

The "Extremely Characteristic" scale implies that the preference is most close to the individual and vice versa for the "Extremely Uncharacteristic" scale. From Fig. 2, it is observed that the students have preferred for a change in the style of thinking. Also, it has been noted that for the Item. No. 7 in Appendix II, the students have preferred for "Uncertainty" scale. This question elaborates the level at which the thinking has to be raised. However, students were not able to judge their own level of thinking. It is the responsibility of the Teacher to induce and expand the student's capability in analyzing the individual thinking capability of the students. Fig. 3 illustrates the design phase related questionnaire. The students have opted for the "Somewhat Characteristic" scale across the Items numbered 10, 11, 13, 14 & 15 as referred from NFC.

The combination of the characteristic ("Somewhat" and "Extremely") scale shows a 50% preference over the grouping of the "Uncharacteristic" scale. The "Uncertain" scale is higher for the Item. No. 14 since it examines the abstract thinking capability of the student. Again the Teacher plays the key role in stimulating the abstract thinking of the students which is considered to be a tremendous task to be fulfilled. From the Fig. 3, it has been observed that the "Extremely Uncharacteristic" selection for the Item. No. 15 is nil. This emphasizes the fact that each and every student irrespective of their level of thinking is passionate towards intellectual thinking. These responses encourage the shifting towards cognitive thinking paradigm for SEOC.

Further investigated for the Implementation and Maintenance phases, the results were positive which confirms the need for cognitive thinking for SEOC. The questionnaire related to Implementation and Maintenance phases are reverse measured with the "Extremely Uncharacteristic" scale being the most nearest to cognitive thinking. Fig. 4 shows the effect with respect to the Implementation phase.

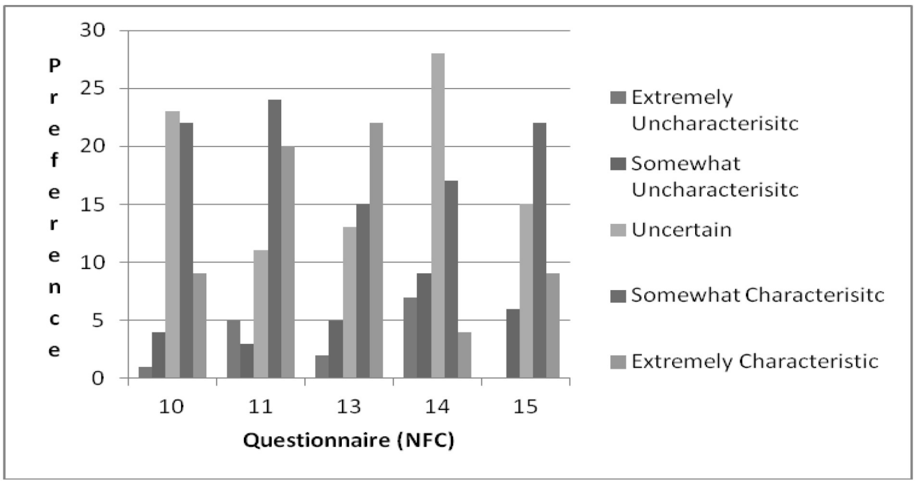

Fig. 3. Design oriented TLP.

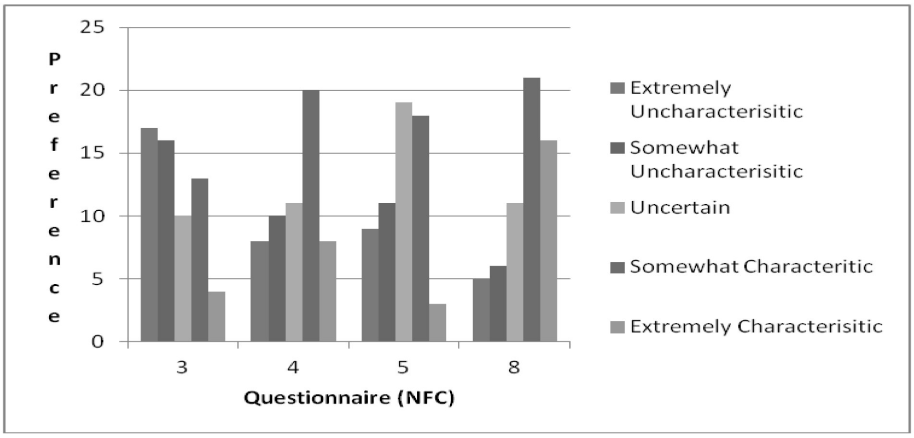

Fig. 4. Implementation thinking.

The "Somewhat Characteristic" scale is relatively higher for Item No. 4, 5 & 8. This is because these questions are related to long-term larger projects which the students have not practically experienced in a real-time environment. However, the students have not moved away from their initial perception i.e. their intention towards improving their thinking skills which is confirmed through their option for Item No. 3. This is a reverse scored item. Hence "Extremely Uncharacteristic" implies strongly agreed.

The Questionnaire related to Maintenance phase is illustrated in Fig. 5. The observations imply that the combined scale of "Extremely Uncharacteristic" and "Somewhat Uncharacteristic" have been the relatively preferred degree of response by the students.

The mixed response for Implementation and Maintenance phase was due to the fact that students presume that the next level of thinking is not part of the Implementation and Maintenance phase. Their preference is higher for analysis and design phase over implementation and maintenance phase. This is because students presume that the analysis and design phases are the building block of the system to be developed and hence will have a high impact on cognitive thinking. Although the students are academically strong, their minimal exposure in implementing and maintaining real-time systems, have forced them to give a diverse response. These factors (Implementation and Maintenance) will have an effect only when they procure real-time experience. However the students have opted for their interest towards new ways of learning through Item No.12 which is a reverse scored Item.

An important aspect is that these factors observed were from the students with different scores, socio-economic background, gender, and regions (urban, rural etc...). Irrespective of their intellectual level of thinking, students prefer to improve their thinking skills with respect to SEOC. The diversity of students has not affected

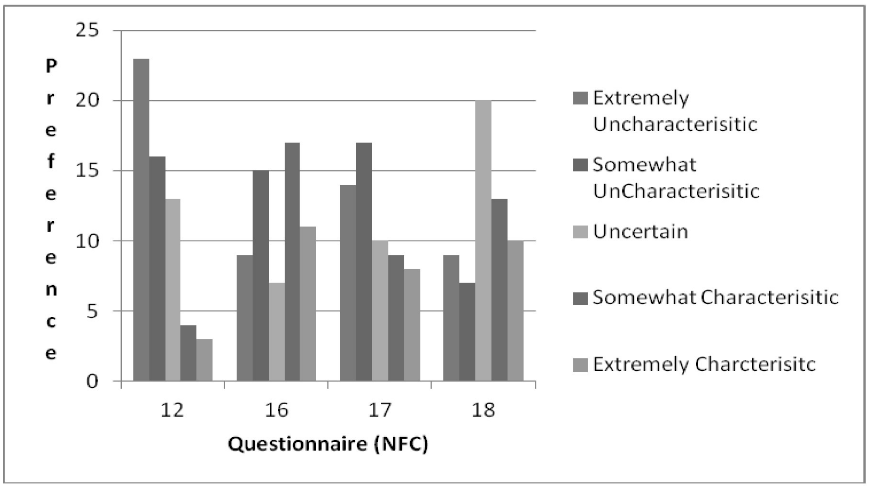

Fig. 5. Maintenance Thinking.

the need for cognitive thinking among the students. This is a positive note to be taken into consideration by the Teachers. This will help in serving the students to meet their goals effectively.

A cognitive based TLP model to improve the thinking capability of the students for SEOC courses have been proposed in this work. This model will help in making the students to perceive the subject through their own way of interaction which will build their confidence level. Wearable Sensor Network can play a major role in formulating the TLP and assessing the feedback of the students within a short duration. This will enable the Teacher -Student to switch from the Lecturing-Listening mode to the Interacting-Thinking mode so that the active participation of the students is made possible. However this initiative requires the detection of the intention towards cognitive thinking which is determined through a Pre-Behavioral Cognitive Detection mechanism. A CCT model is proposed for thinking-learning process evolution which enables the Interacting-Thinking mode of TLP.

In order to validate the above model, a study on the students pursuing Object-Oriented Analysis and Design course has been made to respond for a NFC Questionnaire. These questions were classified as per the Analysis, Design, Implementation and Maintenance phases so as to make the students to respond with reference to the course taken into consideration. The results revealed explored that the students require a combination of conceptual as well as cognitive based knowledge perception so as to realize the core essence of SEOC. The ratio of this combination can be determined by the proposed methodology which will help in building the Teaching-learning model specific to SEOC.

5. Conclusion

In forthcoming generations, a major shift in the TLP has been predicted since engineering students are not actively involving in continuous lecture hours [25]. Rather than assessing the cognitive skills of the students, this work focuses on assessing the need for cognitive based learning from the student's perception. To educate engineers effectively, the NFC scale for SEOC has been highlighted so as to realize the cognitive based learning proficiency of engineering students. The proposed CCT model proves to be a successful method in educating engineering students after judging their cognitive skills. This enhances the way the engineering students can be educated. The proposed Teaching-Learning model significantly educates in promoting the engineering skills of the students.

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Appendix I—NFC Scale

1—Extremely Uncharacteristic
2—Somewhat Uncharacteristic
3—Uncertain
4—Somewhat Characteristic
5—Extremely Characteristic
*—reverse score

Item	EU[1]	SU[2]	U[3]	SC[4]	EC[5]
1. I would prefer complex to simple problems.	1	2	3	4	5
2. I like to have the responsibility of handling a situation that requires a lot of thinking.	1	2	3	4	5
3. Thinking is not my idea of fun.*	1	2	3	4	5
4. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.*	1	2	3	4	5
5. I try to anticipate and avoid situations where there is likely a chance I will have to think in depth about something.*	1	2	3	4	5
6. I find satisfaction in deliberating hard and for long hours.	1	2	3	4	5
7. I only think as hard as I have to.*	1	2	3	4	5
8. I prefer to think about small, daily projects to long-term ones.*	1	2	3	4	5
9. I like tasks that require little thought once I've learned them.*	1	2	3	4	5
10. The idea of relying on thought to make my way to the top appeals to me.	1	2	3	4	5
11. I really enjoy a task that involves coming up with new solutions to problems.	1	2	3	4	5
12. Learning new ways to think doesn't excite me very much.*	1	2	3	4	5
13. I prefer my life to be filled with puzzles that I must solve.	1	2	3	4	5
14. The notion of thinking abstractly is appealing to me.	1	2	3	4	5
15. I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.	1	2	3	4	5
16. I feel relief rather than satisfaction after completing a task that required a lot of mental effort.*	1	2	3	4	5
17. It's enough for me that something gets the job done; I don't care how or why it works.*	1	2	3	4	5
18. I usually end up deliberating about issues even when they do not affect me personally.	1	2	3	4	5

Appendix II

The Item numbers are as referred from NFC so as to identify the grouping according to the phases.

Analysis Phase

1. I would prefer complex to simple problems. (Breaking complex system into subsystems)
2. I like to have the responsibility of handling a situation that requires a lot of thinking.
6. I find satisfaction in deliberating hard and for long hours.
7. I only think as hard as I have to.
9. I like tasks that require little thought once I've learned them.

Design Phase

10. The idea of relying on thought to make my way to the top appeals to me.

11. I really enjoy a task that involves coming up with new solutions to problems.
13. I prefer my life to be filled with puzzles that I must solve.
14. The notion of thinking abstractly is appealing to me.
15. I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.

Implementation Phase

3. Thinking is not my idea of fun. (Mapping Design to Code)
4. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.
5. I try to anticipate and avoid situations where there is a likely chance I will have to think in depth about something.
8. I prefer to think about small, daily projects than long-term ones.

Maintenance Phase

12. Learning new ways to think doesn't excite me very much. (Test Driven Development)
16. I feel relief rather than satisfaction after completing a task that required a lot of mental effort.
17. It's enough for me that something gets the job done; I don't care how or why it works.
18. I usually end up deliberating about issues even when they do not affect me personally.

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