Empowering Deep Thinking to Support Critical Thinking in Teaching and Learning

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ABSTRACT
This research describes learning activities and techniques that improve deep and critical thinking among students. Critical thinking is considered an ultimate goal in MIS education; and learners who reach critical thinking level can achieve the highest learning goals and outcomes. Critical thinking and English communication are considered the two most essential competencies in the 21st century. Therefore, universities have invested significantly in understanding, promoting, and delivering critical thinking in education. Moreover, the learning and education research has invested extensively in critical thinking. In this research, we present and discuss seven learning activities and techniques that initiate deep thinking and promote critical thinking in teaching and learning in order to achieve high level of quality learning. The main focus of this work is in the higher education setting at the level of colleges and universities. We discuss and explain seven learning activities, with examples and tools that will help increase the level of thinking and improve higher order thinking and critical analysis. The presented techniques and examples can be easily applied and adapted into any discipline to help increase and improve higher order thinking among the learners. The preliminary evaluation results are very encouraging.

Keywords
Critical Thinking, Deep Thinking, Quality Teaching

1. INTRODUCTION
The thinking process is a mental process that results in performing certain processing steps by the brain to estimate, induce, or deduce a desired result or decision for a given problem or decision task [1, 10, 17, 21, 22]. It sometimes involves a high level mental activity to reach a reasonable solution, decision, or convergence acceptable to the mind. The formal definition states that critical thinking is the mental process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and evaluating information to reach an answer or conclusion [10, 17].

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In education, critical thinking can be viewed as one of the most important goals, because when they reach critical thinking level, learners can achieve the utmost learning outcomes. Critical thinking, along with English communication, were recognized as the two most essential competencies in the 21st century [11, 25, 26]. Therefore, critical thinking in education is of utmost importance and universities have invested significantly in understanding, promoting, and delivering critical thinking in education. Moreover, the learning and education research has invested extensively in critical thinking. In this research, we make an attempt to discuss techniques and thoughts that improve deep thinking and promote critical thinking in teaching and learning in order to achieve the highest levels of quality learning. In engineering disciplines, in particular, critical thinking is given special importance due to its significance in improving problem solving skills and its relationships to creative thinking and creativity [27].

In its simplest form, critical thinking can be viewed simply as *deep thinking* that can yield better solution or improved decision [1, 11, 25, 26, 27]. This will enable the process of critical thinking to be the process that leads to creativity in thinking and can be viewed as thinking and reasoning at its full strength. Also, in this context, deep thinking can be manifested as a higher level mental process and more focused thinking and reasoning. It can be experienced, for example, when the learner considers the problem from multiple points of view. In this paper we rely on this perception to leverage the concept of deep thinking in higher education settings to reach the level of critical thinking. Specifically, we show that, with certain simple steps, learners can exert and apply some important phases of critical thinking that help them reach their utmost learning outcomes from a given learning task. We attempt, in this paper, to explain *deep thinking* and *critical thinking* in higher educational setting with relatively mature learners. To encapsulate the discussion of critical thinking in a more practical way, we can cast the practical scenario that, in critical thinking (CT), the mental process is performed *twice* on the same task in which the second time includes a more extensive mental activity to produce another, perhaps improved, solution or decision.

The second iteration of the mental process to solve the same problem or decision task is more tiring than the first one and it represents, to some extent, a deep thinking process. Moreover, this second iteration may lead to the first step in critical thinking, see Figure 1. Actually, it is considered a *deep thinking* process because the learner exerts deeper and more extensive brain activity in the reasoning process. In this research, we are interested in how to employ and utilize simple techniques and activities to improve the thinking process and the mental activity of the learners in a given learning task. In other words, we

investigate how to teach and offer students the means to exercise and apply *deeper* thinking in their everyday learning tasks so as to reach the level of critical thinking. Moreover, injecting deep thinking activities in teaching and education is one of the goals of this research aimed at achieving the highest level of quality and analytical thinking among the students. The presented techniques have been evaluated moderately in a number of educational settings and the results are encouraging, and in many situations, impressive outcomes obtained.

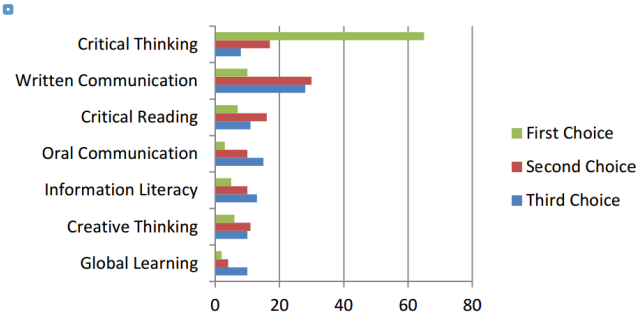

Figure 1: Results of study conducted by University of North Carolina UNC that includes 2822 responses in which *Critical Thinking* was identified as the most essential competency recommended for the UNC system-wide core [25].

2. RELATED WORK

In the academic domain, the interest in critical thinking started few decades ago and continued to progress and increase as a part of research on learning and education. In general, the concept of critical thinking is a very old concept and the interest in it started a long time ago. In the past few decades, however, we started experiencing more attention in integrating, augmenting, and applying critical thinking in education in many content areas and in various branches of science. It has been found that critical thinking is very crucial for delivering quality learning in any subject and content area. Therefore, the learning and education research has invested extensively in critical thinking [4,5,8,9.22]. Also, promoting and applying critical thinking into online education is of particular importance due to the high pace and wide spread of online education with the Internet revolution.

In a research study about critical thinking by Paul, Elder, and Bartell [20], it was shown that an overwhelming majority (89%) of university faculty claim that the promotion of critical thinking is a primary objective of their instruction. However, only 19% could define critical thinking and 77% had little, limited or no conception of how to reconcile content coverage with the fostering of critical thinking [20]. Another study by Bruning (2005) explains the role of critical thinking in online learning environments [7].

In general, three requirements are needed for critical thinking:

− The learner understands the problem (questions, or concept) deeply so that he/she can be close to a highly reasonable solution or answer.

− The educator believes that the learner has gained a complete understanding of the problem or concept.

– The learner has enough information that can be synthesized, arranged, and evaluated to reach high level of mental process of reasoning about the given concept.

Besides, the process of critical thinking can be seen as having two components: the first component includes a set of information and belief generating and processing skills. The second component involves the habit, based on intellectual commitment, of using those skills to guide behavior [8].

CriticalThinking.net defines critical thinking as "reasonable reflective process of thinking focused on deciding what to believe or do" [9]. In Saade et al. [24], critical thinking is a type of a cognitive ability that has a special importance in decision making and judgment processes. Some of the direct and tangible goals for the learner include: getting an in-depth understanding of the problem or concept, initiating and engaging in quality discussion of the concept among students, and being able to develop different approaches to the solution. MacKnight [17] proposes certain tools and strategies for applying critical thinking skill development in the online education settings. In that article, MacKnight emphasizes on collaborative learning, reflection, peer editing, and monitored online discussions [17].

One of the closest projects to this work is the work of Saade et al. (2012).

They present the work and results of applying critical thinking in virtual learning environments. In that project, Saade et al. present and discuss a web-based course to assess critical thinking.

The assessment is conducted to identify which is the most important part for achieving and promoting critical thinking [24]. Their results indicated the significance of interactivity in what students perceived to be critical thinking oriented versus online material as a resource [24].

In addition, in a study conducted by University of North Carolina UNC [25] that collected a total of more than 2800 responses (of which, 58% tenured and tenure-track faculty, 22% non-tenure-track faculty, 6% academic administrator, and 8% academic staff) *Critical Thinking* along with *Written Communication* were identified as the two most important competencies recommended to UNC system-wide core [25].

As also can be seen in Figure 2, critical thinking has an impact on improving problem-solving skills, creative thinking, creativity, and other important competencies [11].

List of 21st-century competencies

- Creativity/innovation;
- **Critical thinking;**
- Information literacy;
- **Problem solving;**
- Decision making;
- **Flexibility and adaptability; learning to learn**
- Research and inquiry;
- **Communication**;
- Initiative and self-direction;
- Productivity;
- Leadership and responsibility;
- **Collaboration**
- ICT operations and concepts;
- Digital Citizenship;
- Media literacy;

Figure 2: List of competencies in the 21st century from [11]. The most essential skills are in boldface

Elements of Critical Thinking: Paul and Elder [21] summarize the elements of critical thinking, or elements of thought as follows:

1. All reasoning has a *purpose*
2. All reasoning is an attempt to figure something out, to settle some *question*, to solve some *problem*
3. All reasoning is based on *assumptions*
4. All reasoning is done from some *point of view*
5. All reasoning is based on *data, information* and *evidence*

6. All reasoning is expressed through, and shaped by, *concepts* and *ideas*
7. All reasoning contains *inferences* or *interpretations* by which we draw *conclusions* and give *meaning* to data
8. All reasoning leads somewhere or has *implications* and *consequences*

Boris and Hall [6] studied critical thinking in a group of graduate students using an online discussion based environment. Students were asked to self-reflect and interact with others using a weekly set of questions. The authors report a significant positive change in critical thinking among the graduate students after they were exposed to Garrison et al. [13] Practical Inquiry Method and asked to use it on a self-directed basis for classroom interaction and dialogues.

In [12], Friston has analyzed brain functions from the free-energy perspective and suggest that the brain functions work to optimize some constant metric, such as the expected reward or expected utility.

Anderson [2] has argued that the college experience should include ways for students to develop creativity within and also outside the formal classroom. Further investigation into the relationship between creativity and critical thinking was carried out by Baker et al. [3]. They argue that although not identical, these two concepts are closely related.

3. CRITICAL THINKING: Activities and Techniques

In this research, we are interested in leveraging and applying critical thinking in the various educational settings where we have a teaching-learning model [12,19,26]. We start with the deep thinking approach to instigate extensive and higher level mental activity for a given learning/thinking problem. We relate the critical thinking process with the learning process as the learning process is a task that requires certain mental activity and thinking or reasoning process to be performed by the brain (*to encode and store the learnt knowledge*). In general, we consider problem solving process is a learning task. A student learns a great deal from solving problems of an assignment in a math course. In the normal model of thinking, the mental activity is performed to produce an acceptable solution to the problem at hand. On the other hand, deep thinking, or deeper level of mental activity, starts when the learner attempts to find another solution, justify, or analyze the first solution. That is, proposing and developing a new solution approach is a key aspect of deep thinking. In normal educational settings, this level of deep thinking is not reached since the normal mental activity produces a good enough solution that makes sense and acceptable to the learner. Therefore, certain simple techniques are needed to instigate the start thinking deeply so as to reach the critical thinking level. One common technique is to ask the student to propose a new solution approach or to solve a given problem in three different ways. In the next section, we present activities and techniques for initiating deep thinking and promoting critical thinking among students in higher educational settings. We evaluated these techniques and the preliminary results are very encouraging.

3.1 Learning Activities to Promote Critical Thinking

In traditional higher education, the levels of learning activities are mostly determined by their difficulty. A learning activity is a task which is a part of the course context and involves some learning and gaining knowledge; and that includes problem-solving assignments, quizzes, exams, discussion groups, and class exercises. There are individual differences among students based on which learning is attained from one activity more than the other. The interest of this work in this paper is in the different ways of injecting deep and critical thinking activities and techniques in the various learning activities. For example, a hard homework assignment may not involve deep thinking or critical analysis as expected when compared to some other simpler tasks that involves deep thinking. We present and explain the following seven learning activities and how and why critical thinking is involved or utilized in these activities:

1: Produce multiple solutions to a given learning problem.
2: Solve problem *P* without using method *m.*
3: Explain the differences between the two methods m_1 and m_2 for problem *P*.
4: Design criteria to distinguish between and compare two concepts.
5: Find the mistake in a given solution, or statement, for a given concept.
6: Recap the most important points in a given topic.
7: Summarize a given subject or story.

Learning Activity 1:

- Producing multiple solutions to a given learning problem: In a Computer Science introductory programming course, an assignment problem asks the learner to write a program in two different ways.

Example: Write a program to produce the *Fibonacci* sequence of *n* numbers where *n = 25*. That is, the program will print the first 25 numbers in Fibonacci sequence (e.g., 0 1 1 2 3 5 8 ..etc). Normally, the professor had in mind several solution approaches for this program (also fairly advanced and brilliant computing students can think of several methods) including: −using simple loop, − using recursion, and − using dynamic programming. Usually a student thinks of a simple loop as follows:

Method 1:

```
n = 25
f0 = 0
f1 = 1
print f0  f1
for i = 1 to n-2
    t = f0
    f0 = f1
    f1 = f1 + t
    print f1
end-for
```

and here is the second approach (using recursion):

Method 2:

```
n = 25
for i = 1 to n
   print Fib(i)
end-for

Function Fib( n ):
   if n = 0 return 0
   if n = 1 return 1
    Else
     Return Fib(n-1)+Fib(n-2)
End-Function
```

In tasks such as this, when the student solves this problem with the first method the brain has exercised only the first iteration of the mental activity with no deep thinking or extensive mental activity applied. To instigate and initiate deep thinking and more extensive mental process the learner should think about and propose a different solution method for this problem.

Learning Activity 2:

- Solve problem P without using method m. In this case, method m is the direct and straight forward way to solve problem P without exerting any deep thinking. Quality thinking at a deeper level will start when the learner tries to reason about and think of another method for this problem.

Example: Write a program (or algorithm) to find the result of this multiplication {123*456} without using the multiplication * operator.

Learning Activity 3:

- Explain the differences between the two different methods *m1* and *m2* for solving problem P. The learner in this case is required to explain the logic (rationale) behind the two methods (*m1* and *m2*) for solving problem P. This is an ideal case when the learner straightforwardly can solve the problem with the two methods. However, deep thinking starts when the learner thinks about the logic behind the two methods rather than just solving the problem with these two methods. In [18], Noris argued that when students provide rationale or justification of their choice of solution, they validate their CT [18].

Example: The instructor might ask: We discussed in the class two different methods (e.g. *Dijkstra* and *Bellman-Ford*) to solve the shortest path problem. Explain clearly the differences between these two methods. In this activity, a learner uses analytical thinking and deep analysis to produce a good answer. Another example: In an undergraduate data structures class, students are asked to differentiate between *quicksort* and *heapsort*. The students can understand and implement the individual algorithms in a mechanical fashion. However, deep learning happens when the students try to understand and explain the fundamental differences between the two sorting algorithms such as the memory requirements and time complexity.

Learning Activity 4:

- Design criteria to distinguish between and compare two concepts*:* Given two approaches to solve an MIS problem, the learner is asked to develop criteria to compare the two approaches. In this case, the learner will have to think of and search for the most important aspects of the given concepts (*analytical thinking*) to be used as criteria for comparison. This Learning Activity was shown in a study by Rao that *compare-and-contrast* reveals important characteristics between two concepts and can yield deeper understanding and higher learning [16]. Further, it was one of six CT skills identified in that study [16].

Example: In an MIS course, students were asked to develop a prototype for simple information system IS for comparing universities in the US. This activity transforms learning into another domain by asking the students to develop criteria and set of metrics to compare universities *X* and *Y*. The student will have to pursue deep thinking about what is significant (most important aspects) about universities to be used as comparison criteria; and this may lead to the following:

> *Cost of study; reputation and national ranking; location and region; sports teams; how large (number of students); activities and student life; scholarships*.

At the end, this assignment will amount to the question: *how can you compare two universities in the US?* The developed set of criteria and metrics will apply to comparing any two universities in the US. This activity is different from the third activity as it addresses and deals with concepts whereas the third activity works with methods for solving a given problem.

More examples: Students are not required to compare two concepts, rather, students are asked to develop comparison criteria. For instance, students in a biology class are asked to compare the *prokaryotes* and *eukaryotes*. Another example, also from biology, the learners are required to compare *genes* and *proteins*. The students know *genes* and *protein*s; however, they might not be aware of the most important aspects between *genes* and *proteins* in the biological context. In this example, genes and proteins are two types of what is known as *gene products* and the set of criteria developed to compare them can be applied (to some extent) to any two gene products like *RNA* and *DNA*.

Learning Activity 5:

- Find the mistake in a given solution, or statement, for a given concept: For a given solution of a problem or statement that looks fairly good and correct, the students are asked to find and explain the mistakes (*i.e.,* to critique) or find inconsistencies in the given solution. This is a deep thinking task as the errors are usually not extracted directly from the given solution or statement.

Example: The instructor gives a computer program that computes the PCA of a given dataset. The instructor injects a subtle error in the solution. The students are asked to locate and correct the error.

Learning Activity 6:

- Recap the most important points in a given topic: In this activity, we would like the learner to apply deep thinking in a journey to seek the most important aspects or points in a given topic. The topic can be as simple as one chapter in the textbook. For instance, summarizing the most important points in Chapter Five in one page.

Example: In a computer networking class, the instructor asks the students, in a paper writing assignment, to write a two-page report summarizing the most important concepts about the IP protocol. Another example, a professor asks the students to summarize the three to five most important concepts in object-oriented programming.

Learning Activity 7:

- Summarize the subject or story: summarizing a topic is different than recapping or summarizing the most important concepts in a given topic as explained in the previous learning activity (L.A. 6). In this activity, a topic, narrative, or story is given to the learner to read and summarize it in one paragraph, like writing an abstract of a paper.

3.2 Practical Examples

In this section we discuss, from various disciplines, some practical examples of learning activities and problems that activate deep thinking among learners and promote critical thinking.

Example 1:

Many university disciplines require a course in computer programming including in Management Information Systems. In such *a* course, students are asked to write a program (*we use here pseudo-code to illustrate the idea*) to compute the multiplication of two numbers (e.g. *123*32*) in three different ways. Straightforwardly, students will use the direct method (method 1 below) and it will be a very simple task. The deep thinking starts when students begin to think about a second way to produce the same result:

Method 1:
```
x ← 123
y ← 32
z ← x * y
```

Method 2:
```
x ← 123
y ← 32
z ← 0
Loop y times
   z ← z + x   /* repeat y times: add x to z*/
end-loop
```

Method 3: this is used only if one of the two terms in the multiplication is a power of two. In this case, the learner needs to think more deeply to realize that multiplying any number (*e.g.*, 123) by another number (e.g., 32) which is a power of two (*e.g., 32 = 2^5*) can be done by a simple *shift left* operation available in many languages:

```
x ← 123
y ← 32
z ← x << 5
```

{Note: << is the left shift bitwise operation}

This assignment enables students to exert more thinking effort in producing three different solutions to this problem (*Learning Activity 1*). Moreover, the learner in this example may be wondering which method is the best. This is again a step towards critical thinking. The learner, on comparing these three methods, may ask the questions based on what criteria can we decide the *best* solution among these three methods.

Example 2:

In low level programming course (*i.e., assembly language*), which is needed for computer science and computer engineering disciplines, the *shift* operation is important and students are asked to: write program code to do the following shift operation *without* using *shift* instructions in three different ways:

```
shl  ax,1.
```

That is, the program should shift to the left all the bits of register AX (in *Pentium* machines). This can be done using the following three solution methods:

Method 1:
```
add  ax, ax;
```
Method 2:
```
mov bx, ax
add ax, bx
```
Method 3:
```
mov cx, ax
Lp:  inc ax
     loop Lp
```

Example 3:

Perform the following addition operation without using the addition/plus (*i.e.,* +) operator: *y ← x + z*. This example is for *Learning Activity 2* discussed above and can be done as follows:

```
x ← 123
y ← 456
z ← x
Loop y times
   inc z   /* repeat y times: increment z by 1 */
end-loop
```

Example 4:

In software project management, one of the important concepts to learn is the requirement or what is called *Software Requirement Specifications SRS*. This concept basically includes what are the functions that a software project will do. Typically, understanding the requirements of a project correctly is one of the most important aspects of a software project. Most importantly, the learner is asked to discuss the requirements and to highlight (and *explain*) the *most important* requirements in the project. For that, the learner will have to conduct some critical analysis and deep thinking to derive and justify the most important requirement(s).

Some of these learning activities seem like challenges, and Grabau [14] in his study about effective teaching and learning strategies showed that 'challenges to students' thinking' is one of the effective strategies for promoting critical thinking.

Example 5:

In a given course, and towards the end of the course, students are required to write down *the most fundamental and central question* in that course. That is, what is the main question that this course addresses? For instance, to answer this question in a database course, a student may propose the following question as the most fundamental: *How to design a normalized database for ABC company and write an efficient query to retrieve names and salaries of those employees of age 65 or above?*

In order to answer such a problem, the learner should deeply think about what is the most important concept that we learn in this course and so the main question will be around that concept.

3.3 Evaluation and Preliminary Results:

We evaluated these learning activities and techniques with preliminary experiments in a number of studies and the results are impressive. The main tool of results is the survey mechanism that allows students to provide feedback after applying a critical thinking activity. We administered and conducted multiple activities from activities 1 through 7 above in the form of problem solving assignments with a number of selected students. Then after each activity, the student fills a survey that includes few feedback questions that requires answer from 1 to 10 where 1: *not at all* and 10: *strongly agree*. The assignments were given limited time (*normally between 1 – 2 hours per assignment*) and open-book format to allow the learner to search for solutions.

- This assignment requires a deeper level of thinking than normal assignments:
(not at all) 1 2 3 4 5 6 7 8 9 10 (strongly agree)
- I believe that I am now better in handling this kind of problems that require deep thinking:
(not at all) 1 2 3 4 5 6 7 8 9 10 (strongly agree)
- I think I have learned a new skill for critical and deep thinking:
(not at all) 1 2 3 4 5 6 7 8 9 10 (strongly agree)
- Doing more of this kind of problems will significantly improve my problem solving skills:
(not at all) 1 2 3 4 5 6 7 8 9 10 (strongly agree)
- I do not mind working on more assignments and problems like these from time to time to improve my deep thinking:
(not at all) 1 2 3 4 5 6 7 8 9 10 (strongly agree)
- Every student should practice and work on this kind of problems from time to time:
(not at all) 1 2 3 4 5 6 7 8 9 10 (strongly agree)

The students overwhelmingly agreed that they exerted extra and extensive in-depth thinking (question 1) and reasoning about the given learning task. Moreover, they believed they attained more quality learning and they can engage in deep discussions about the concepts. All the preliminary results are very encouraging. Currently we are still in the process of conducting more extensive evaluations, analyses, and experiments.

4. DISCUSSION AND CONCLUSION

The interest of this work is how to stimulate and leverage deep and critical thinking through learning activities that can be applied in various educational settings. Some of these activities and studies have been used/applied and produced significant learning improvement results. To measure the outcomes of critical thinking activities normally students start using more advanced terms and statements that indicate critical analysis, deep thinking and higher order mental process. Students also can get engaged in more in-depth discussions about the subject concepts. Moreover, in our previous similar research, we reported few survey results which indicated that the learners were very satisfied with the level of learning due to the learning activities that involve deep and critical thinking [1]; we also observed significant improvement is students' performance in terms of academic grades. The presented learning activities, in this study, can improve students' thinking process hence promoting critical thinking. The second learning activity (*solving problem without using method m*) seems to be the hardest as it requires really deep level of thinking and some kind of extensive mental process. Overall, higher, or highest, levels of learning can be achieved upon reaching critical thinking. Therefore, education research continues to invest significantly in critical thinking and its relationship to teaching and learning. A search on Google scholar for the keyword '*Critical Thinking*' in December 2014 produced 200,000 hits, spanning books, scientific journal and conference papers and articles. A majority of these hits are from scholarly publications from 2009 onwards. We repeated the search for the words '*Critical Thinking*' to be in the title of any scholarly work using Google Scholar engine (note: Google Scholar retrieves only scientific and scholarly publications based on verified .edu email addresses of the authors) we got 9,000 scholarly publications just in the past five years. We also searched Microsoft Academic search site (http://academic.research.microsoft.com) for the same keyword '*Critical Thinking*' in the title or in the text of publication and we retrieved 12345 publications since 2008. Moreover, searching IEEE *Xplore* (http://ieeexplore.ieee.org) returned 510 articles having '*critical thinking*' in the title, just in the last five years 2009 – 2014 (with an average of more than 100 articles each year). These are scientific publication from sciences and engineering disciples (IEEE, Institute of Electrical and Electronics Engineers, is the world largest professional association of scientists and engineers). Finally, we search the ACM Digital Library with keyword '*critical thinking*' and received over 23,000 results of which over 13,000 are in the last five years 2009–2014. All these results indicate obviously that Critical Thinking has been an active area of research production in academia the last several years.

In Conclusion: We presented and discussed some applied techniques and thoughts in higher education for stimulating and leveraging critical thinking through simple class learning activities. We presented and discussed with examples seven learning activities for promoting critical thinking. Simple learning activities with higher order thinking can help learners exert more extensive mental process for a given problem thus leveraging critical thinking. The presented techniques for promoting critical thinking have been tested to a certain extent while the extensive evaluation is still in progress and the preliminary results are very encouraging. Students, after exercising these critical thinking activities, strongly believe that they exercised deeper levels of thinking and more extensive mental activity; hence more learning was attained. Students also are more confident that they can engage in focused and in-depth discussions about the concepts of the subject. We are currently in the process of designing and conducting more extensive and comprehensive evaluation with in-depth analysis of results.

It has been, and will continue to be, highly acceptable that critical thinking is of very high significance in education; and critical thinking was recognized as one of the two most essential competencies in the 21st century. Harvey et al. [15], and Razzak [23] emphasize that deep learning involves critical analysis, linking of ideas and concepts, and creative problem solving and can lead the learners for life in the 21st century. Therefore, education research continues to invest significantly in critical thinking and its relationship to creative thinking, problem solving skills, and creativity. Engineering disciplines are paying special attention to these core competencies (*critical thinking*, *creativity*, *communication*, *collaboration*, *problem-solving skills*, *inter-personal skills*) that engineering graduates should possess and employers are looking for such competencies.

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