Recognizing the need for rich contextualization in the classroom and applying it with modified Bloom's cognitive domain taxonomy for successful teaching of Physics 106 (Physics II – electricity, magnetism and light)

Matthew E. Edwards
Department of Physics, Chemistry & Mathematics
Alabama A&M University
Normal, AL 35762

ABSTRACT

Engaging students to teach new concepts and to have students achieve individualized learning with the successful integration of those new concepts with their existing knowledge has been and remains the primary goal of college education. In this study drawing on information gathered over the past 2 plus decades, my findings have led me to develop two new separate ascending teaching-structures that are significantly helping me with content delivery, and simultaneously helping my students achieve greater success in mastering the material of my Physics 106 (Physics II, Electricity, Magnetism and Light) classes. These two teaching-structures, called Contextualization Teaching and Rich Contextualization Teaching (RCT), with each structure relying on various aspects of a modified Bloom's cognitive domain taxonomy and on my description of and when to use each structure, along with my introduction of "subject learning convergences," are described and illustrated here. Finally, of students with open-minds and mentally connected to the subject being taught, I make the suggestion that my two ascending teaching-structures can be used for teaching such students new-concepts in any academic course where engaging students to teach new concepts represents the primary focus.

Key words: Bloom's cognitive domain taxonomy, Subject Learning Convergences (SLCs), Contextualization Teaching, Rich Contextualization Teaching (RCT), engaging to teach, teaching-structures, outcome gauging, and exchange mechanisms

1. INTRODUCTION

When teaching Physics 106 (Physics II - calculus based Electricity, Magnetism and Light), I routinely use a new cognitive teaching tool that I have named "Contextualization Teaching." As a new teaching-structure, Contextualization Teaching is comprised of three independent parts or blocks, which are:

1) Standard teaching methods
2) Teacher's attributes
3) The last component and the first three components of Bloom's cognitive domain taxonomy

In this regard, Contextualization Teaching has been designed for initially and continuously gauging as needed, and then engaging to teach students new concepts and have them achieve content mastery with the successful integration of the new concepts with their existing knowledge. The successful integration of existing knowledge and new concepts as manifested through individualized learning has been and remains the primary goal of college education.

For me, the way I use Contextualization Teaching facilitates my delivery of content materials and helps make the abstract nature of Physics II [1-2] concepts less intractable to my students. In Fig. 1a, I show a visual rendition of Contextualization Teaching, with its three independent blocks or parts.

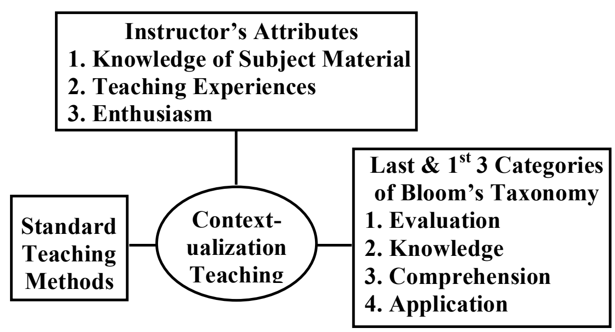

Fig. 1a: Contextualization Teaching diagram

The standard teaching methods, as contained in the left block, are the traditional teaching patterns used in most physics classes: initial assessment of the class is implemented, discussions of content material occur; the instructor issues selected assignments; the assignments are provided to the instructor; the assignments are graded and returned to students; tests and other learning projects are given and graded; and finally, letter grades are awarded to students for course performance. The entirety of a course can move forward in this manner. I have used this pattern over the years and shall continue to use it in the future, as a beginning effort. Next, from left to right in Fig. 1a, the topmost block identified as the instructor's attributes has three subcomponents, which are given as:

1) Knowledge of the subject material
2) Teaching experiences
3) Enthusiasm

Needless to say, of the instructor's attributes, subcomponent 1, the instructor's knowledge of the subject material, is critical for efficacious or effective teaching. The instructor simply must have the requisite content knowledge of the course material that is to be conveyed to the students, otherwise, less than adequate teaching occurs in the course, and only a diminished return can be gained from the instructor's presence in the class. Also similarly and at least as critical as the instructor's knowledge of the subject material is, is the instructor's teaching experiences, often without which the instructor is ill equipped to handle the average Physics II class, typically having more than 20+ students. If developed properly, the instructor's knowledge of the subject material and teaching experiences lead the instructor to having a greater intellectual-depth and a keenness in the presentation of the course material to the students.

Finally, as the third subcomponent, of the instructor's attributes, enthusiasm for the course represents the ending part of the Instructor's Attributes block. Without enthusiasm for the course, the critical motivation mechanism for sharing between the instructor and students is missing. Essentially, in this regard, the course has little or no *rasa* or synergy and thus is robbed of an effective exchange mechanism. These teaching attributes remain viable and applicable for me, and I find myself constantly applying them and working on how to expand my knowledge of all physics courses that I teach, including Physics II, where developing new teaching-structures to teach more effectively, with Physics II as the illustrated course, is the focus of this study.

The third and final block of Contextualization Teaching, as shown on the right side in Fig. (1a), equates to uniting the last category and the first three categories of the original Bloom's cognitive domain taxonomy together into one block. Once combined, the four categories with their separate identities—Evaluation, Knowledge, Comprehension, and Application [3-5] are functional as a group. The essence of this part of Contextualization Teaching is designed for the instructor to have a method to gauge the class capacity for learning Physics II, initially, and then to have readily available several menu items from these categories of the taxonomy, with which the instructor can use to engage the class in various teaching sessions, exchange new concepts and assess outcome gauging more effectively than when using standard teaching methods only, the first of three blocks of Contextualization Teaching.

Table 1 shows the modified Bloom's cognitive domain taxonomy, where Contextualized Teaching, as a teaching tool, contains only categories 1-4. The remaining categories, 5-6 of the taxonomy (Analysis and Synthesis), are to be addressed and used later.

As is well documented, Benjamin Bloom in the mid 1950's chaired the committee that created this intellectual classification-scheme or taxonomy, and from that time forward, the taxonomy has been labeled Bloom's cognitive domain taxonomy. Below, in Table 1, the modified Bloom's cognitive domain taxonomy depicts my variations of the original scheme.

Table 1: Modified Bloom's cognitive domain taxonomy

1 Evaluation (6)	**2 Knowledge (1)**	**3 Comprehension (2)**
Appraise Assess Support Choose Compare Defend Est. Judge Predict Rate Select Evaluate	Locate Define Write Recite Memorize Identify Describe Label Name Recognize State	Compare Match Summarize Confirm Transform Restate Explain Relate Change Predict Extend
4 Application (3)	**5 Analysis (4)**	**6 Synthesis (5)**
Make Interpret Solve Classify Show Model Modify Choose Collect	Select Analyze Compare Construct Classify Separate Categorize Survey	Hypothesize Construct Formulate Organize Develop Combine Add to create Produce

Moreover, in strategizing for teaching effectiveness, I consider Bloom's original categories (1) & (2) (my categories 2 & 3) in Table 1, to be the low-level intellectual grouping for Physics II instructional engagements and categories (3)-(5) (my categories 4-6) to comprise the high-level grouping. Evaluation, the 6th category of the original Bloom's cognitive domain taxonomy (my category 1), as used to gauge student performance initially, is positioned as number (1) and is used as needed in my Contextualization Teaching. The low-level grouping 2 & 3 and category 4 of the high-level are used more or less during each class session, and, to that extent, Contextualization Teaching as a teaching-structure helps me in routine day-to-day instruction in my Physics II classes. Essentially, the modified Bloom's cognitive domain taxonomy, with re-ordered categories, provides in pictorial form a menu of items that support engagement, information exchange and outcome gauging at this first-level critical thinking in Physics II. To reiterate and summarize, Contextualization Teaching comprises the followings:

1) Standard teaching methods
2) Instructor's attributes
3) Modified Bloom's cognitive domain taxonomy, 1-4 categories, only

However, on some occasions, even for students who are subject-wise connected, difficult content material arises during some class sessions where a greater effort to achieve teaching effectiveness is required on the part of the instructor. In my Physics II classes, I find that when Contextualization Teaching as described above is insufficient for teaching effectiveness, a "Subject Learning Convergence" (SLC) is imminent, or one has already occurred in the class. At this point, for me as the instructor, my teaching approach at this moment is critical to the overall success of the class. Such a failure on the instructor's part to recognize the reality of SLCs places the class in the dangerous predicament of not being able to meet the course learning outcomes, in its totality. My experiences suggest that better at engaging teachers know from experience where SLCs exist in their classes or courses and can prepare for their impact well before they occur.

Simply stated, for me as a teacher of Physics II, I recognize that an SLC is imminent or about to occur when either two or more new concepts must be used together, two or more mathematical equations (formulas) must be manipulated simultaneously, or two or more similar yet variant procedures or operations are required in concert. To teach effectively or to manage my Physics II class properly during these situations, during SLCs, I have progressed to using an expanded teaching tool that is beyond the scope of Contextualization Teaching. I call this new teaching-structure "Rich Contextualization Teaching," or "RCT." This tool, as a higher teaching-structure with five parts, is depicted in Fig. 1b below.

As an ascended teaching-structure, RCT, is an enhancement to my routine or day-to-day teaching tool as folded under Contextualization Teaching; RCT embraces teaching engagement, information exchange and outcome gauging at a higher level than Contextualization Teaching does. RCT, as used in my Physics II classes, more than doubles the probability that at least 80% of my Physics II students shall successfully master the course material. As Fig. 1b shows, the components of RCT in comparison to Contextualization Teaching display two additional yet critical blocks. The first additional block, (right, mid level), contains simple Persistence having three elements: rehearse, recite and redo. The persistence block of RCT is virtually self-explanatory. For the Physics II student to embrace several newly acquired abstract concepts at once or a voluminous amount of material that is to be integrated, such a student must be engaged with obvious and consistency repetitions, recitation and practices to learn effectively or must embrace the adage: "rehearse, recite and repeat (redo) for excellence."

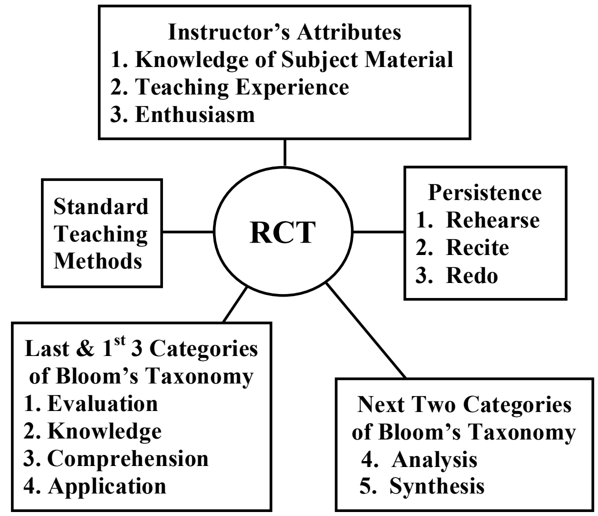

Fig. 1b: Rich Contextualization Teaching (RCT) diagram

The final block of the new RCT teaching-structure, comprising analysis and synthesis, is designed to engage the Physics II student in higher-level intellectual thinking, which on some occasions requires deconvolving or separating existing information, on one hand, or the combining of concepts, on the other. Both the analysis and synthesis categories of modified Bloom's cognitive domain taxonomy provide additional and significant menu items that add to the menu items already available through the simpler Contextualization Teaching. The additional menu items further illumine content understanding to allow better engagements for cognitive learning or exchange to occur to meet the course learning objectives.

Finally RCT, comprised of five independent blocks, allows me to engage fully for effectiveness teaching and exchanging of knowledge with my Physics II class on the occasions of SLCs. In this regard, RCT facilitates me to meet the course learning outcomes in such critical teaching sessions. Together with Contextualization Teaching, RCT completely spans the entire spectrum of what is needed for effective teaching in my Physics II classes. What are some subject learning convergences in Physics II? I address this question next.

Scores of SCLs occur doing the duration of a course in Physics II. However, in this regard, I illustrate only four such convergences with physics II problems in this study. In brief, the four convergences (problems) to be considered are:

I. Obtain, using Kirchhoff's laws, the unknown currents in a simple multi-loop electrical circuit when other circuit parameters are known.

II. Obtain using the derived resistivity equation of metals the unknown temperature of a lamp's filament when a given electrical current exists in the filament, and other relevant parameters are known.

III. Obtain the equivalent resistance R_{eq} and the equivalent capacitance C_{eq} when a "resistor bank" and separate "capacitance bank" are given simultaneously.

IV. Obtain the magnitude of the force on an accelerating electron in a crossed magnetic- and electric fields (both fields are present in the same space at the same time).

The below section, labeled "Four Illustrations of RCT in Physics II," shall consider problems having SLCs and how to address them effectively when using the new ascended teaching-structure RCT.

2. SCOPE AND RATIONALE FOR CONTEXTUALIZATION TEACHING AND RICH CONTEXTUALIZATION TEACHING (RCT)

As stated previously, a SLC for my Physics 106 class is imminent when one of the following actions is poised to occur:

1) To manipulate several mathematical equations in concert
2) To connect several simultaneously occurring concepts (some new ones and some old ones)
3) To use several new or recently learned concepts in concert
4) To process a voluminous amount of material

In this regard, I find that a tandem of material and complicated informational items do not hinder the students of my Physics II classes. Instead, the obstruction to learning occurs only from the concert or voluminousness or similarity yet different material making, on these occasions, difficulty in effective learning of new concepts. These are the sorts of occurrences that some of my Physics II students find extremely undesirable and, therefore, are worthy of avoidance if possible.

In this regard, I find that the characteristic of students needing both Contextualization Teaching and RCT is not unique to my students at Alabama A&M University (AAMU). I have observed this behavior in all places where I previously taught Physics II, ranging from Fayetteville State University, Fayetteville, NC, to the University of Pittsburgh in Pittsburgh, PA, and Spelman College in Atlanta, GA. My thoughts are that this behavior exists in all academic institutions and plaque some Physics II students of all races and socioeconomic groups, when they study Physics II. In summary, the components of Contextualization Teaching can handle routine day-to-day class sessions in Physics II and RCT, as a more advanced teaching structure, can handle all such occasions when SLCs occur.

Finally, both these new teaching techniques, Contextualization Teaching and RCT, do not involve or require the injection of extra hands-on activities into the Physics II course or the removal or the diminishing of Physics II abstractness as another learning tool, Contextualized Teaching and Learning (CTL), requires. CTL engages the learning process using hands-on and direct experiences. While these adjustments meet the needs of non-abstract course, CTL does meet completely satisfies the requirements of abstract courses, such as Physics II as it currently exists. On the other hand, my Contextualization Teaching, along with the ascended RCT, which also handles SCLs, is ideal for abstract courses and those courses where content descriptions cannot be changed. Thus, with my two teaching-structures, open-minded and subject connected students can learn effectively and manifest to have a true fundamental understanding of a given subject material.

Relevant Sequence Course Descriptions

PHY 105 (Physics I – 4 hrs): This is the first part of a calculus-based physics course designed for sciences, engineering and technical majors. The goal is to acquaint students with the language, notation and nature of physics. The approach to the mathematical solution of physics problems is strongly emphasized throughout the course. Topics to be covered include mechanics, fluid heat and thermodynamics. The student will perform at least ten experiments. Prerequisites: None. Co-requisite: MTH 125.

PHY 106 (Physics II– 4 hrs): The second part of a calculus–based physics course designed for sciences, engineering and technical majors. The goal is the same as for Physics I. Topics to be covered will include electricity, magnetism and light. At least ten experiments will be performed by the student. Prerequisites: PHY 105. Co-requisite: MTH 126.

3. METHOD: FOUR ILLUSTRATIONS OF RCT IN PHYSICS II

I. A Multiloop Electric Circuit Problem

RCT modified Bloom's components for engaging students: a. APPLICATION **-** collect, solve and illustrate; b. ANALYSIS - analyze and construct; c. SYNTHESIS - formulate and combine results

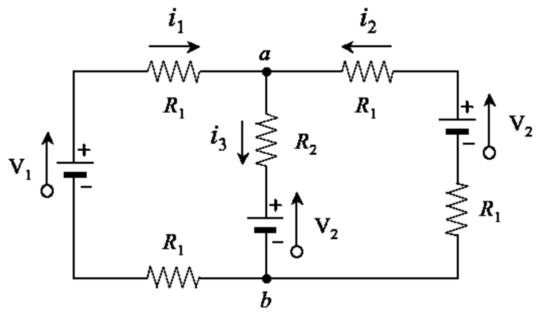

Fig. 2: Multiloop electric circuit

In Fig. 2, all the required parameters are given:

$$V_1 = 6\text{V},\ V_2 = 12\text{V},\ R_2 = 8\Omega, \text{ and } R_1 = 4\Omega$$

If considering the batteries to be ideal, find the magnitude and direction of the current in each of the three branches. Since there is no way to reduce the circuit to a simpler, equivalent circuit by using Ohm's law, we use Kirchhoff's voltage and current rules to obtain a set of three simultaneous algebraic equations. Then we solve the three equations to obtain the unknown currents, in magnitude and direction.

Kirchhoff's current rule applied to node b yields:

$$i_3 = i_1 + i_2 \tag{1}$$

Kirchhoff's voltage rule applied to the left-hand loop yields:

$$-i_1R_1 + V_1 - i_1R_1 - i_3R_2 - V_2 = 0 \tag{2}$$

Kirchhoff's voltage rule applied to the right-hand loop yields:

$$-i_2R_1 + V_2 - i_2R_1 - i_3R_2 - V_2 = 0 \tag{3}$$

The students are led to solve this set of equations by substituting eq. (1) into eq. (2) and eq. (3) to get the two independent equations, having two unknowns, i_1 and i_2. After substituting the given parameters, the two equations become:

$$\begin{aligned} 8i_1 + 4i_2 &= -3 \\ 4i_1 + 8i_2 &= 0 \end{aligned} \tag{4}$$

Resulting values are $i_1 = -0.5\text{A}$, $i_2 = 0.25\text{A}$ and $i_3 = -0.25\text{A}$. The current direction of i_1 and i_3 are reversed as signified by the negative currents.

II. Resistor Bank and Capacitor Bank Problems

RCT modified Bloom's components for engaging and gauging: a. APPLICATION: solve, illustrate and interpret; b. ANALYSIS: analyze, construct and compare; c. SYNTHESIS: formulate and combine

Often one has to determine the equivalent resistance for a resistor bank when the bank contains both series and parallel resistors. Resistors in series combine in a linear manner, while resistors in parallel combine in a reciprocal manner. In this problem, the students are given capacitors in Fig. 3a and resistors in Fig. 3b. When looking into each circuit from the battery V, find the equivalent capacitance in Fig. 3a and the equivalent resistance in Fig. 3b.

Series Resistors $\quad$ Series Capacitors

$$R_{eq} = R_1 + R_2 \qquad \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \tag{5}$$

Parallel Resistors $\quad$ Parallel Capacitor

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \qquad C_{eq} = C_1 + C_2 \tag{6}$$

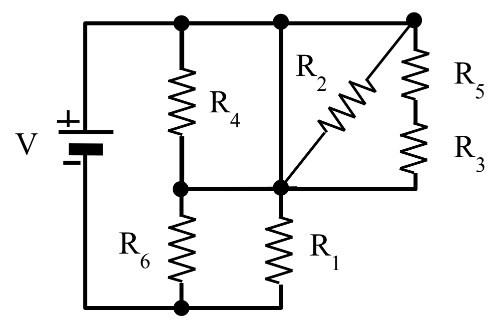

Fig. 3a: Resistor bank electric circuit

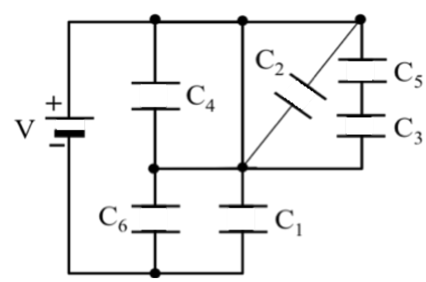

Fig. 3b: Capacitor bank electric circuit

The given parameters for each circuit are:

$C_1 = C_6 = 3\text{F}$ $\qquad$ $R_1 = R_6 = 3\Omega$

$C_3 = C_5 = 4\text{F}$ $\qquad$ $R_2 = R_5 = 4\Omega$

$C_2 = C_4 = 2\text{F}$ $\qquad$ $R_2 = R_4 = 2\Omega$

Using the required formulas for combining resistance in the first case and the capacitors in the second case, the results are:

$C_{eq} = 3\text{F}$ $\quad\quad R_{\text{eq}} = 1.56\Omega$

III. Temperature Coefficient of Resistivity: Simultaneous Equations with Divisional Cancellations

RCT modified Bloom's components for engaging and gauging: a. APPLICATION: solve, illustrate and interpret; b. ANALYSIS: analyze, construct and compare; c. SYNTHESIS: formulate and combine

For a common metallic flashlight bulb, made of tungsten, the resistivity depends on the temperature of its filament. Consider that the bulb is rated 0.3A and 3V, the current and voltage, respectively, at the higher operating temperature. If the resistance of the filament at room temperature (20°C) is 1.25Ω, what is the temperature of the filament when the bulb is on? For tungsten, the temperature coefficient is:

$$\alpha = 4.5 \text{ x } 10^{-3}(\text{K}^{-3}) \quad (7)$$

Other relevant equations to solve this problem are:

$$V = IR \quad (8)$$

$$R = \rho \frac{\ell}{A} \quad (9)$$

$$\rho = \rho_0[1 + \alpha(T - T_0)] \quad (10)$$

$$T_K = T_C + 273 \quad (11)$$

when

$$T = T_0,\ \rho = \rho_0, \text{ and } R = \rho_0 \frac{\ell}{A} \quad (12)$$

Now, using the ratio of the resistance at the high temperature to the resistance at the lower temperature yields:

$$\frac{R_H}{R_L} = \frac{\rho_0[1+\alpha(T-T_0)]\frac{\ell}{A}}{\rho_0\frac{\ell}{A}} = 1+\alpha(T-T_0) \quad (13)$$

After inverting the above ratio, the result becomes:

$$T = T_0 + \left(\frac{R_H}{R_L} - 1\right) \quad (14)$$

On substituting the given parameter, the final equation and numerical value are, respectively:

$$T_K = (20{+}273) + \frac{1}{4.5x10^{-3}K^{-1}}\left(\frac{3V/0.3A}{1.25\Omega} - 1\right) \quad (15)$$

and $T_K = 1{,}849K$ or $T_C = 1{,}576°C$.

IV. Electric and Magnetic Fields Concepts

RCT modified Bloom's components for engaging and gauging: a. APPLICATION: solve, illustrate and interpret; b. ANALYSIS: analyze and construct; c. SYNTHESIS: formulate and combine

In this context, simultaneous equations will result. An electron has an initial velocity of:

$$12km/s\hat{i} + 15km/s\hat{j} \quad (16)$$

and a constant acceleration of:

$$2 \text{ x } 10^{12} m/s^2\hat{i} \quad (17)$$

in a region in which uniform electric and magnetic fields are present. Find the electric field $\vec{E}$, if the magnetic field is given by:

$$\vec{B} = 400\mu T\hat{i}\ , \quad (18)$$

The students' solution proceeds in the following manner: an electron's mass and charge (See Fig. 4) are:

$$m = 9.1 \text{ x } 10^{-31}kg \text{ and } q_e = -1.6 \text{ x } 10^{-}19C \quad (19)$$

The required equation is:

$$\vec{F} = m\vec{a} = q_e\vec{E} + q_e\vec{v} \times \vec{B} \quad (20)$$

The results of inverting this equation yield:

$$\vec{E} = \frac{m}{q_e}\vec{a} - \vec{v} \times \vec{B} \quad (21)$$

On substituting the parameters, the electric field vector $\vec{E}$ becomes:

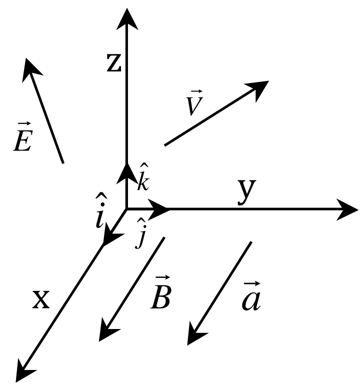

Fig. 4: Electron moving in electric and magnetic field

$$\vec{E} = \frac{9.11x10^{-31}kg}{-1.6x10^{-19}C}(2x10^{12}m/s^2\hat{i}) - (12x10^3 m/s\hat{j} + 15x10^3 m/s\hat{k}) \times 4x10^{-4}T\hat{i} \quad (22)$$

The resultant electric field becomes:

$$\hat{E} = -11.39N/C\hat{i} - 6N/C\hat{j} + 4.8N/C\hat{k} \quad (23)$$

4. DISCUSSION

In previous sections, the definitions of Contextualization Teaching and RCT were presented, along with a description of each and four illustrations of using RCT. The two individual teaching-structures are complete for their intended purpose. Contextualization Teaching enables the Physics II instructor to teach effectively during routine day-to-day class sessions. Contextualization Teaching is particularly applicable when students are learning less abstract concepts or abstract concepts that are presented in a tandem or sequential manner.

On the other hand, RCT arises to provide the Physics II instructor with a teaching-structure to engage the class session effectively when an SCL is imminent, or one has already occurred. At the onset of an SCL, higher cognitive levels of thinking and processing of material must be used in Physics II. The SCL typically occurs when material occurs in a voluminous amount, or simultaneous manipulations are required in formulas or equations, or numerous newly learned concepts occur in concert.

In order to recognize the onset of SCLs, this study indicates that the Physics II instructor must be sufficiently knowledgeable of the subject material and know beforehand that a higher level teaching-structure, such as, RCT is needed. Not knowing ahead of time or not being able to adjust to an SLC quickly after it occurs places the class in jeopardy of not meeting the class learning outcomes. But, knowing at the onset that an SCL should occur at a particular junction in the course or upcoming class session and being equipped with teaching-structures, which can be utilize in teaching through such an SCL, are paramount to the success of the Physics II class.

5. RESULTS

The followings are several obvious results of this study:

1) A comprehensive definition of Contextualization Teaching has been given. It has three parts (blocks), which are:
    a) Standard teaching methods
    b) Instructor's attributes
    c) The last category and first three categories of Bloom's cognitive domain taxonomy
2) The meaning of SLC has been given in full detail.
3) The definition of RCT with its five parts (five blocks) has been given, which are the previous three parts of Contextualization Teaching (a – c) and additionally:
    d) The two other components of Bloom's Taxonomy - analysis and synthesis
    e) Persistence
4) Four illustrations using RCT have been demonstrated using course material from Physics II.
5) The author is quite convinced that using Contextualization Teaching, when the participating students are open-minded and mentally connected to the subject material, can be used routinely in all academic courses where engagement to teach is the primary concern and that using RCT can and should be used in such courses when SLCs arise.

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