A Protocol-Based Blended Model for Fluid Mechanics Instruction

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A PROTOCOL Based Blended Model for Fluid Mechanics Instruction

ABSTRACT

A personalized and media-rich learning framework called “Knowledge and Curriculum Integration Ecosystem” (KACIE) has been developed and implemented in a junior level fluid mechanics course in Fall 2016 and Spring 2017. This model shares characteristics of blended instruction as well as a flipped classroom, with an overall structure that includes the application of established principles emerging from the learning sciences and from cognitive neuroscience. These principles have taken form in the KACIE model as classroom protocols or written instructions to scaffold and guide teaching and learning by faculty and students respectively. In KACIE, the course has been presented as a sequence of 55 concepts that each connect to its pre-requisites. Scripted and animated short video lectures of 2-6 minutes duration and mandatory in-class activity sheets were developed and used for teaching each of the 55 concepts. This paper presents the details of the KACIE model and its impact on fluid mechanics instruction by comparing relevant data from the Fall 2015 control semester when the same course was offered in a traditional teaching environment. The results show that the media-rich KACIE intervention in an HBCU has significantly improved students’ academic engagement and success, substantially reduced failure rate, and enhanced their critical thinking ability.

I. INTRODUCTION AND BACKGROUND

Twenty-first century engineering education in the US has benefited greatly from the attention and fresh thinking in recent years, yet it continues to face significant challenges that prevent broader national success [1-3]. Educators have increasingly realized that relying solely on traditional lectures is ineffective for engaging a new generation increasingly connected to the digital world, and have therefore initiated numerous efforts to integrate technology into the teaching-learning process [4, 5]. In addition to this, there is an increasing recognition that learning complex engineering concepts can benefit from more in-depth clarity pre-requisites than previously understood [6]. Teaching-learning models that blend technology with traditional lectures to ensure quality of instruction have been reported promising for engaged and effective learning of higher level skills [7, 8]. Exploiting more fully the potential of online web-assisted tools along with face-to-face meaningful and engaging interactions inside class rooms, the blended learning model has often successfully merged traditional teaching methods with computer assisted instructional models of modern era [9].

In one variation of this approach, online video lectures and other instructional materials were used for skill preparation and learning before the normal hours designated for class room engagement. A viable instructional model emerged from this, involving subsequent face-to-face interaction of faculty with students through problem solving, active learning, and skill application, within the class room environment [10]. This model is intended to help shift the role of teacher from that of a traditional lecturer to a role that is more prominently that of a mentor, trainer or a consultant, who actively participates with students in their learning activities. The model is reported to be promising for providing engaged learning experience for engineering students [12, 13]. Numerous studies indicate that these technology-integrated instructional methods, including those
that formally feature classroom flipping, provide opportunity for active and interactive learning. These methods are promising, particularly in engineering education. Many have significantly improved academic success in terms of problem solving skills, quick learning, and deeper-structure understanding and use of concepts [14, 15]. Many studies report that such methods have reduced failure rate in comparison to instruction methods that merely rely on traditional lectures for content delivery and classroom management [16].

A sizable literature indicates that student engagement in classrooms has strong correlation to their academic and professional success [17-20]. Student engagement in engineering classrooms is a challenge for several reasons. These include lack of preparation, self-efficacy, perceived ability, socio-economic factors and less-effective course delivery methods [21-28]. Additionally, each of these can contribute to a sense of alienation that exacerbates disengagement. Engineering courses require continuous development of sophisticated mathematical skills throughout the curriculum. Moreover, learning of complex engineering concepts at higher level classes requires minimum pre-requisite knowledge, the lack of which can lead to attention problems, aversion to the course, and finally to overall poor performance. While such issues are partly addressed by curriculum rules which enforce mandatory pre-requisite courses, a major fraction of students still enrolls in higher-level courses with the minimum grade allowed to move on in these pre-requisite courses. With deficient or subpar foundations, they may face more difficulties and eventually drop out or change their engineering major for academic survival. While this issue prominent in all engineering programs across universities, it becomes more critical in Historically Black Colleges/Universities (HBCUs).

Based at an HBCU-designated school with extensive support from the National Science Foundation (NSF), we have studied the phenomenon of the gap between our expectations and student performance in the mathematical competencies and preparation for advanced coursework [57-59]. As observed, such weaknesses connect to the level of student academic engagement – both inside and outside of the classroom. This study, attempting to address student weaknesses by addressing low academic engagement levels, led to the design and exploration of the Knowledge and Curriculum Integration Ecosystem” (KACIE), in which a framework that organizes research-based principles from the learning sciences and from cognitive neuroscience into practical protocols or patterns for classroom learning and teaching. The overall aim has been to foster a research-based and media-rich classroom ecosystem for engaged and improved learning experience that effectively prepares students to succeed in upper level courses.

The model we present blends critical and established research findings in learning with multimedia, shared screen feedback, and other digital tools to significantly alter what can be called the attentional intensity of the course [29-32]. Students are more engaged both in and out of class time with course material, and instructors can direct attention to the particulars of each student’s unique concept-building journey. The KACIE model shares, at the college level, important aspects of cognitively-guided instruction approach (CGI) as well as related theories of learning progressions at the elementary school level, in that it focuses on building coherence of student thinking at both a stepwise and large structure level by drawing the instructor into a more finely grained involvement in process [34-35]. It represents an advance over CGI in its reliance on diverse technologies, and of course the target population differs. The detailed descriptions of this model and methods used in the control and the intervention semesters are discussed next.
II. METHODS

The Fall 2015 semester was used for collecting control data for comparison purposes, where traditional methods have been adopted for course instruction. The KACIE model has been implemented for instruction in Fall 2016 and Spring 2017. Table 1 summarizes distinctions between the methods used in the comparison and intervention periods.

**TABLE I SUMMARY OF METHODS USED IN TRADITIONAL AND KACIE APPROACH**

<table>
<thead>
<tr>
<th>Activity/Method</th>
<th>Traditional</th>
<th>KACIE</th>
</tr>
</thead>
</table>
| **Course Content** | Categorized as 8 Chapters  
Power point slides that that cover each chapter provided as instructional material after each lecture  
Extensive use of lecture notes and demonstrations in whiteboard | Categorized as 55 concepts and 22 sub-concepts  
Short-scripted, animated video lectures on each concept posted and available to students 24x7  
Demonstration in class using these pre-made videos | KACIE based material development and delivery |
| **Pre-class** | None | Inform student the concepts to be discussed. Ask them to watch KACIE video lectures (2-6 mint duration maximum) |
| **In-class** | Lecture, students takes notes, solve problems based on white board demos | Lecture using KACIE video (5-15 min.)  
Each student work on his/her KACIE sheet developed for EACH of the concepts  
Mandatory submission of sheets  
Peer discussions allowed  
Teacher work with individuals on demand  
Repeated view of video lectures  
Zone of proximal development  
Quizzes using Microsoft surface pros, digital ink and screen sharing | |
| **Assessment** | Assessment of homework on each chapter (20% credit) and feed-back  
Summative assessment by Four tests for two chapters (80% credit) | Assessment on KACIE sheets for each concept (20% credit) and feed-back  
Summative assessment by Four tests for 10-15 concepts together (80% credit)  
Critical thinking assessment (CAT)  
Test before and after |
In the comparison semester, the course content is categorized as eight chapters, similar to the representation in a standard text book that is adopted for the course. This junior level, three credits, fluid mechanics course has three contact hours every week during the semester. Content of each chapter is delivered in a traditional manner, with extensive use of the white board, homework assignments for each chapter, and a summative test every two chapters. 20% weight of the course grade is given to the homework assignments, and 80% weight is given to the four summative tests that span the semester in equal intervals. At the end of semester, letter grades were assigned based on their performance in homework assignments and four summative tests.

During the intervention semester, students see the course differently. They see the courses as 55 interrelated concepts rather than as book chapters. The course organization centers on learning, not on divisions in a book. While this may seem a subtle difference, making the concepts rather than chapters of paramount salience fosters a concept-focused mindset. Short video lectures and in-class activity sheets for each of these concepts become part of the learning experience. These instructional materials were prepared following various KACIE protocols, the details of which appear in sections V and VI. In-class KACIE activity sheets permit more active interaction between students and between students and the instructor. They also created a form of embedded assessment, evaluated on a weekly basis as part of the homework grade assessment and as a means for formal and timely performance feedback. In the intervention semester, four summative tests integrated 12-16 concepts at a time also allowed a comparison with the chapters in use in the earlier comparison group. Critical thinking assessment skills of students, both before and after intervention, were measured using the critical thinking ability test (CAT). Finally, an end-of-the-semester student survey was conducted to document the feedback from students on various aspects of the intervention. More specifics of methods used in intervention appear in section VI.

III. KACIE Course Delivery Framework

In the KACIE model, a course comes to students explicitly as a model of interconnected concepts and sub-concepts. The key feature of this approach is the use of presentation and interaction tools that are developed based on several protocols that appear in Figure 1.

The KACIE model has two components. In the primary component, the course syllabus appears in an integrated modular concept format, in which complex engineering concepts are presented as networked sub-concepts in a web interface, creating a virtual space of connected knowledge. Each of these networked concepts and sub-concepts are further linked to several learning tools, such as animated concept videos (2-6 minutes duration) and mandated student activities. These concepts are designed to leverage the latest insights from established theories of neuro- and cognitive science with the help of several protocols, or systematized guidance based on research in the learning sciences and in cognitive neuroscience. The details of the KACIE protocols appear in Fig. 1.

The protocols used for concept delivery are identified by the key principles they represent: P1 – Connect to old/prior information, P2 – Create neural connections, P3 – Active learning component, P4 – Repeated use of neurons, P5 – An emotional component, P6 – Zone of
proximal development, P7 – Patterns of meaning, P8 – An element of choice and P9 – Create a cognitive map. These designated protocols were identified from research reported on neuroscience that explored neuro-physiology of learning. Each of these constructs was studied separately and extensively for its respective significance in education at different levels [38-49]. Although a detailed description of established knowledge on learning sciences is beyond the scope of this paper, we hope that the key terms identifying the protocols will convey their importance in creating a classroom ecosystem that emphasizes both knowledge formation and fidelity to the course curriculum.

**Fig. 1** Elements of KACIE framework: The protocols used for concept delivery are: P1-Connect to old/prior information, P2-Create neural connections, P3-Active learning component, P4-Repeated use of neurons, P5-An emotional component, P6-Zone of proximal development, P7-Patterns of meaning, P8-An element of choice and P9-Creative a cognitive map.

In this paper, the protocols used for developing instructional content of each concept in the fluid mechanics course follows through two examples; Concept 1- Density and Concept 32-Bernoulli’s principle. Please refer to KACIE videos (http://bit.ly/kacie-videos) developed for these concepts, C1 and C-32, for a better understanding of the use of protocols as explained below.

**PROTOCOL 1** or “P1: Connect to old/prior information” entails identifying conceptual pre-requisites that can be connected to the concept C1 density. The video starts with a review of the basics of physical units and unit conversion, as these concepts are required as pre-requisites. After introducing and reviewing pre-requisites, the protocol “P2: Create neural connections”
introduces the actual concept with examples to generate neural connections. In this example, the definition of density as mass per unit volume is introduced with a few illustrations. In P3, an active learning component is introduced by creating an imaginary situation in which students were asked to solve practical examples where they could calculate the density of a fluid. P4 creates an opportunity to repeat this exercise and P5 searches for emotional components that can be related. The famous “eureka” story of Archimedes is related to the concept of density and a revisit of this story then reinforces this concept. P6 identifies a challenging problem which is solved with direct assistance from the faculty using a screen sharing technology that helps to scaffold the student’s proximal development zone. P7 presents a higher-level perspective of the same concept. A more accurate definition of density used in a continuum approximation is explained here. P8 searches for patterns of meaning of this concept. Introducing various types of matter having different density and its correlation to its mass and volume will help the student generalize and to generate patterns of meaning that permit transfer of understanding. Finally, P9 entails to generate a cognitive map for this concept, to summarize the core idea of the concept, which can be retrieved later when this concept is required as pre-requisite for another higher-level related concept.

As another example, six protocols used for concept 32, ‘Bernoulli’s equation’ as follows: P1 connects to old information and seeks review of the concepts steady flow, streamline, and inviscid flow (they are concepts C-29, C-30 and C-31 respectively) since concept 32 requires these as pre-requisites. A review of these pre-requisites will refresh memory, allowing refreshed neural associations or connections. P1 also reviews the basic concept of Newton’s second law of motion applied to a particle in motion and relation between force, displacement and work since these sub-concepts are also connected to this concept. The conservation of mechanical energy as applied to a particle in motion is also reviewed using P1, since Bernoulli’s equation describes the same principle to a flowing fluid. P2 presents a mathematical formulation of Bernoulli’s principle followed by a simple equation, describing the principle of conservation of mechanical energy of an inviscid, incompressible, steady, irrotational flow. The meaning of each term in the equation is explained in this section. P3 applies this principle to a practical problem to find velocity of a given flow configuration. P4 mandates description of another problem for reinforcement of the same idea. P5 brings a real-life problem, for example, calculation of air speed using a pitot tube fixed to an aircraft, which is slightly harder than problems discussed in section P3 and P4. This problem also uses the scaffolding proximal development zone protocol, in which students were asked to solve this in a collaborative manner using a shared digital workspace with “invisible” supervision of faculty who could help through helping within the workspace. P6 brings a summary of this principle as a cognitive map. In the ‘Bernoulli’s concept’ example, only 6 protocols were used. On average, 5 protocols and one video were used for each of the 55 interconnected concepts the curriculum entitles.

Scripted short video lectures and other activities, such as concept tests, help to foster student engagement inside and outside the classroom. In the KACIE model, the learning begins with creating the concept movie that involves subject research, protocol identification, script writing, animation, audio and video making, editing, and uploading to a web interface. These components are accessible to all the students before the same concept is formally introduced in the class. Along this process, activities associated with this concept are also prepared in advance as “KACIE sheets”, which include short quizzes that test conceptual knowledge, along with
problems of varying levels of complexity that enable the instructor to assess the student’s knowledge. This follows in-class exposure to the concept, using the 2-6 minutes long KACIE movie. Depending on the interconnection between the concepts, 2 to 3 concept videos along with a short instructor led discussion take place in class followed by students attempting the KACIE sheets. Note that each KACIE sheet surveys the frequency of individual views, as well as students’ understanding level in a 0 to 5 scale after completing all prescribed activities.

These short videos are continuously available on a larger screen in the class, though students can also access these videos through their personal devices. In a typical 50-minute lecture, 20-30 minutes are allotted for working on the KACIE activity sheets. Several students complete this sheet within the class period, and the rest submit it during the next class if additional time is required. The activity sheets comprise 20% of the overall course grade. These regular activities help the instructor give timely feedback to the students and direct them to the available videos to learn identified missing concepts. Once all students submit these sheets, solutions are discussed in the class, followed by one final review of the concept. Students who still struggle to complete the activity sheet are given an opportunity to re-submit these sheets for minimal bonus that adds to the homework grade points. The 80% of the course grade is decided over four summative tests, conducted on a quarterly basis, which altogether evaluate 12-15 concepts. Before each quarterly summative evaluation test, an in-class, cumulative ZPD exercise is performed using a digital collaborative work space. Tablet computers allowing digital ink (Microsoft Surface™ Pro tablets to date) are used in the ZPD protocol activities; two students work together to solve difficult problems in a collaborative manner on a single device. Screen-sharing software (Lanschool™ or Mythware™) is used for online monitoring of student activities by the faculty for instantaneous feedback on the real-time problem-solving exercises.

![Fig. 2 Flow chart of a concept delivery in KACIE model](image-url)
A flow chart that shows activities of concept delivery in KACIE model appears in Fig. 2. The intention behind these content-rich, media-rich and feedback-rich strategies is straightforward: This effort seeks to facilitate more immediate, precise, and successful interaction between each individual student, the engineering skills they are acquiring, and the classroom instructor.

IV. KACIE Model Implementation and Intervention

During the exploration phase, 78 scripted concept and sub-concept videos were developed for Fluid Mechanics. On average, 4-6 protocols were used in each concept movie making. These concept video lectures are made available to students always and are well ahead of concept delivery. These movies, designed to leverage the maximum attention span, are 2-6 minutes in duration and are available to students through a YouTube channel http://bit.ly/kacie-videos. Figure 3a shows screenshot of modular presentation of the fluid mechanics course in the YouTube channel and 3b shows its statistical report from September 2016 to March 31, 2018.

The students enrolled and participated in Fall 2016 and Spring 2017 are n=21 and n=33 respectively. During the control period (Fall 2015 semester) n=20 students were enrolled and participated. A student survey indicates that, on an average, a student watched concept movies 4-6 times with an average view time of nearly 10-15 minutes. This repeated watching is self-regulated. It provides a context for the students to make conceptual connections and repairs at a pace they determine. To date these videos are watched nearly 34000 times with a total view time of more than 55000 minutes over 125 countries as per YouTube statistics (fig. 3 b). This intervention also used shared screen software that enables instructors to see student work in real-time [50]. The shared screen arrangement follows a logic model, in which students are aware that their work is always visible to the instructor and the instructor is always available to see and respond to questions. The intent is to promote student engagement in class time by providing “sightlines” between the instructor and the student, making student thinking more visible to the instructor, enabling a higher feedback level to students as the concepts connect into a coherent whole. Using the experience-sampling method (ESM), this approach has been documented to significantly increase student engagement in undergraduate mathematics courses [51].

Screen sharing, as well as the incorporation of pen-based input for solving engineering problems in class, enables what has been termed “microgenetic analysis in giving feedback”, whereby the college instructor can see conceptualizations more clearly and form more exact inferences in real time about student conceptualization [52]. This enables rich, real-time feedback in ways that correspond closely to the protocols that KACIE emphasizes, most directly to Vygotsky’s zone of proximal development [53, 54].

V. KACIE Intervention-Data and Analysis

Fig. 4 shows a comparison of the test scores of the KACIE group in the two intervention semesters (2016 fall and 2017 Spring) with the control group (2015 fall). As indicated by the figure, the KACIE students outperformed their counterparts in all four tests conducted in this
class. To keep the data comparable, the tests administered were identical and with a similar level of difficulty. A statistical analysis using one-way Analysis of Variance (ANOVA [55]) with the type of course delivery as an independent variable shows a significant effect (F = 17.27, p < 0.01). The data are not homogeneous in the variance but follow a normal distribution. Hence ANOVA is robust to the violation of homogeneity and is used for the analysis. Further, comparisons are performed within the scores of each test. Independent sample t-tests without assuming homogeneity of variance is used for these comparisons; the results appear in Table II.

Fig. 3 Screen shot of a) the modular presentation of concepts in the YouTube channel (http://bit.ly/kacie-videos) b) statistical report
The evidence in Fig. 4 and Table II suggest that the students who grasped their course material through the KACIE framework have outperformed those who learned the material outside of the KACIE framework. The comparisons were statistically significant for the first three tests for both intervention semesters. In the fourth test, no statistical significance was observed, but even in this test, students in the KACIE group outperformed the control group. The fourth test was given, both in control and KACIE intervention period, as an open book exam. This resulted in a higher grade, and may be the reason for the slightly higher p-value.

![Comparative Average Test Scores](image)

**Fig. 4** Comparison of average test scores across the control and KACIE classes.

<table>
<thead>
<tr>
<th>Test</th>
<th>t-statistic</th>
<th>p-value</th>
<th>Effect Size (Cohen’s d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>2.03</td>
<td>&lt;0.05*</td>
<td>0.48</td>
</tr>
<tr>
<td>Test 2</td>
<td>2.03</td>
<td>&lt;0.05*</td>
<td>0.83</td>
</tr>
<tr>
<td>Test 3</td>
<td>2.06</td>
<td>&lt;0.05*</td>
<td>0.85</td>
</tr>
<tr>
<td>Test 4</td>
<td>2.05</td>
<td>0.06</td>
<td>0.60</td>
</tr>
</tbody>
</table>

* statistically significant comparisons with \( \alpha = 0.05 \)

Fig. 5 shows the distribution of various grades in the two groups, consolidated across all the exam scores. Typically scores less than 60 are failure in the test. As evident from the Fig. 5, the failure rate in tests, with KACIE intervention, fell from 38% to 3% in comparison with the control period. Another interesting feature noted in fig. 8 is the visible shift in the grade range. A large percentage that failed during control period was re-distributed to C and B grades. The number of students with an A grade (>90%) also increased in both the intervention periods.
Comparison of Critical Thinking Ability of Students before and after intervention

Since KACIE focuses on research developments in the learning sciences and in cognitive neuroscience the course was expected to instill deep learning and develop critical thinking in the students. To identify the degree to which their critical thinking ability was improved after attending a KACIE model course, critical thinking assessment test (CAT) developed by Tennessee Tech University [56] was administered as pre- and post-test for the treatment group. The CAT instrument consists of questions derived from real world situations that require short answer and essay responses. This measures the students’ ability to evaluate and interpret given information, problem solving skills, creative thinking and effective communication skill. The detailed scoring guide and the scoring mechanism ensure scoring reliability and test-retest reliability. The validity of this measure has been established in the literature [56].

The CAT test was administered to a class of 21 students in Fall 2016. However, only 17 tests were used for the final scoring, as one student missed the pre-CAT test or due to multiple unanswered questions. 88.2% of the population were African American and 11.8% were of Spanish, Hispanic or Latino ethnicity. The 94% of the students considered themselves as primarily English speaking. 29.4% seniors, 64.7% juniors and 5.9% sophomore were present in the distribution.

For identifying the improvement in the critical thinking ability of the students attending the KACIE course, a pre- vs post-test analysis has conducted. Two-tailed t-test was used for the comparison. Table III shows the mean scores and the pair-wise statistical comparison results for each question. In general, students showed a significant improvement in their scores for each question except at two occasions (and the decrease in score was not significant, statistically). For two questions, the t-test showed statistical significance (measured at p-value) less than 0.1. Overall, the total score on the CAT test improved from 12.59 to 17, resulting in 35% change after the KACIE intervention and this difference was statistically significant (p<0.001). We believe that the use of carefully prepared formative assessment tools, such as KACIE worksheets, that promotes critical thinking ability skills in relation to a concept they have
mastered, might have influenced this change. Other academic and non-academic factors that spread across the intervention semester must also have influenced this change. This interesting observation needs further study and analysis in the future.

**TABLE III CRITICAL THINKING ASSESSMENT DATA (FALL 2016)**

<table>
<thead>
<tr>
<th>Skill Assessed by CAT Question</th>
<th>Institution/Department</th>
<th>Pre Mean</th>
<th>Post Mean</th>
<th>Probability of difference*</th>
<th>Effect Sizeb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summarize the pattern of results in a graph without making inappropriate inferences.</td>
<td></td>
<td>0.53</td>
<td>0.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluate how strongly correlational-type data supports a hypothesis.</td>
<td></td>
<td>0.41</td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide alternative explanations for a pattern of results that has many possible causes.</td>
<td></td>
<td>1.24</td>
<td>1.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify additional information needed to evaluate a hypothesis.</td>
<td></td>
<td>1.18</td>
<td>2.00</td>
<td>*</td>
<td>+.82</td>
</tr>
<tr>
<td>Evaluate whether spurious information strongly supports a hypothesis.</td>
<td></td>
<td>0.53</td>
<td>0.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide alternative explanations for spurious associations.</td>
<td></td>
<td>0.69</td>
<td>1.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify additional information needed to evaluate a hypothesis.</td>
<td></td>
<td>0.47</td>
<td>0.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determine whether an invited inference is supported by specific information.</td>
<td></td>
<td>0.41</td>
<td>0.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide relevant alternative interpretations for a specific set of results.</td>
<td></td>
<td>0.47</td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separate relevant from irrelevant information when solving a real-world problem.</td>
<td></td>
<td>2.41</td>
<td>2.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use and apply relevant information to evaluate a problem.</td>
<td></td>
<td>0.71</td>
<td>1.35</td>
<td>**</td>
<td>+.93</td>
</tr>
<tr>
<td>Use basic mathematical skills to help solve a real-world problem.</td>
<td></td>
<td>0.65</td>
<td>0.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify suitable solutions for a real-world problem using relevant information.</td>
<td></td>
<td>0.88</td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify and explain the best solution for a real-world problem using relevant information.</td>
<td></td>
<td>1.50</td>
<td>1.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explain how changes in a real-world problem situation might affect the solution.</td>
<td></td>
<td>0.65</td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CAT Total Score</strong></td>
<td></td>
<td>12.59</td>
<td>17.00</td>
<td>***</td>
<td>+.67</td>
</tr>
</tbody>
</table>

(U.1 - U.3 = small effect; U.3 - U.5 = moderate effect; >U.5 = large effect)

<table>
<thead>
<tr>
<th>N</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAT Total Score</strong></td>
<td>PRE</td>
<td>17</td>
<td>1.00</td>
<td>30.00</td>
</tr>
<tr>
<td>POST</td>
<td>17</td>
<td>4.00</td>
<td>28.00</td>
<td>17.00</td>
</tr>
</tbody>
</table>

**Average Total Points Attained**

<table>
<thead>
<tr>
<th></th>
<th>PRE</th>
<th>POST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
VI. KACIE INTERVENTION- STUDENT SURVEY AND ANALYSIS

Table IV summarizes the details of student survey at the end of the intervention semester. Survey shows that students fully agreed about the important role of the videos provided in their overall understanding of the course materials. Data points out that the KACIE sheets did assist in increasing their knowledge of the course materials. The survey also shows that the students did accept the idea of deliverance of course materials as concepts. The 32% of the students responded that they have deficiency with the pre-requisites, and it is limiting their learning achievement. 29% of students responded that they watched the concept videos 1-3 times. A majority (57%) watched them 3-6 times. 14% responded that they watched movies 10-14 times. Nearly half of the student population responded that they are more satisfied with KACIE in comparison to other courses. The other half had the opinion that they are satisfied with KACIE just like any other course. Finally, nearly all responded that KACIE sheets were useful for better understanding and learning the concepts.

TABLE IV STUDENT SURVEY DATA TABLE

<table>
<thead>
<tr>
<th>Q.</th>
<th>Statement</th>
<th>Completely agree (%)</th>
<th>Somewhat agree (%)</th>
<th>Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The supplementary videos provided helped to understand the course material in better manner</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>2.</td>
<td>These videos equipped me to self-learn the materials in my own pace</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>3.</td>
<td>These videos helped me to prepare for tests with more confidence</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>4.</td>
<td>My confidence level increased as the course proceeded</td>
<td>73</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td>Lack of pre-requisite has played a role limiting my achievement.</td>
<td>19</td>
<td>13</td>
<td>68%</td>
</tr>
<tr>
<td>6.</td>
<td>I would like to have additional video materials for other courses</td>
<td>74</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>7.</td>
<td>Course description in terms of ‘concepts’ is very positive</td>
<td>79</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>8.</td>
<td>On average, how many times you watched the concept videos</td>
<td>1-3 times</td>
<td>3-6 times</td>
<td>6-10 times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>29 %</td>
<td>57 %</td>
<td>14%</td>
</tr>
<tr>
<td>9.</td>
<td>Overall satisfaction in this course delivery in comparison to other courses</td>
<td>Better satisfied</td>
<td>Satisfied just</td>
<td>Not satisfied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>47%</td>
<td>like any other</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>course-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>47%</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>In class KACIE sheets were useful for better understanding of concept and learning</td>
<td>Agree</td>
<td>Somewhat agree</td>
<td>Disagree</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67%</td>
<td>34%</td>
<td>0</td>
</tr>
</tbody>
</table>
VII. CONCLUSIONS:

This paper reports implementation and impact of a brain-based course delivery framework, titled KACIE in fluid mechanics course. The primary aim of this framework is to address the lack of engagement and academic deficiencies in engineering classrooms in an HBCU. These include the phenomenon of the gap between our expectations and performance of students reaching upper level engineering. Based on the theories on neuro-cognitive learning, we suggested and implemented several protocols integrated with multi-media for instruction. The entire course material preparation process is guided by these protocols. The content is presented in a media-rich format, and the students have access to these media within and outside the classroom. The intervention data indicate that students who are instructed through the KACIE framework outperform peers in comparison group. Further, this intervention shifted grade patterns within the class. More students in the KACIE group scored higher grades (C and above) compared to those in the control group, in which a substantial proportion of the class scored an F. The critical thinking assessment test (CAT) score before and after intervention shows a 35% change in overall score of the student group. In summary, these results indicate that the newly-implemented framework is effective in improving student grades and their learning in an upper level engineering course. Currently, the scalability of this approach and the transferability of the materials are being tested across disciplines at other universities.

Limitations and Future Directions

The data reported in this paper is based on the implementation of the KACIE framework in a single upper-level engineering course at Tuskegee University. To generalize the results, data need to be collected from other mechanical engineering courses as well as preparatory courses such as mathematics or physics. The flow of information through a series of courses taken by undergraduate students also needs to be studied. These issues are addressed in ongoing studies which will be reported later. Further, the scalability of this approach will also be studied in other engineering schools in the future. Although this study focuses on the tools, course content, elements of structure and process of learning, it does not specifically address the role and influence of faculty on the learning environment.

Acknowledgements:

Support for this work is provided by the National Science Foundation Award No. DUE 1504692 and 1504696. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors would like to acknowledge Dr. Zengjun Chen for assisting with CAT test evaluation. Partial findings from the preliminary studies have been presented in the ASEE Annual Conferences in 2016 (Paper #16685) and 2017 (Paper #17913).

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