Enhancing the Kinesthetic Learning Activities (KLA) in CS Education Using Mobile Applications

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ABSTRACT

Many Computer Science courses at the University level follow the traditional lecture and textbook method. By using these methods to teach difficult Computer Science concepts, it disengages the students interest from learning the subject as it requires in depth problem solving approaches to master these concepts proficiently. With hands on learning approaches such as Kinesthetic Learning Activities (KLA), students are engaged and motivated when it comes to learning a variety of computer science concepts. These non-traditional methods help students retain the material in an effective and efficient way without having to memorize complex terms by reading unnecessary text. While KLA approaches are effective in helping students learn, incorporating mobile devices for KLA not only keeps the students engaged but also helps them understand the concepts being taught better. This approach allows a group of eight participating students to have the opportunity to learn basic concepts such as Switch Statements, Quicksort, and Decimal to Binary conversions by engaging with the mobile app. It also allows non-participating students to observe the activity step-by-step on the dashboard via mobile devices. Furthermore, students are also exposed to learning via technology.

Keywords

Kinesthetic Learning Approaches, mobile devices, computer science education

1. INTRODUCTION

The problem with many universities, online classes, and other educational institutions is that most courses are taught using the traditional lecture and textbook format. This involves listening to lectures during class and reading the assigned course textbook to understand the material. By following this approach, students have to read, listen to lectures, and understand a lot of terminology and concepts through incomprehensible lectures and superfluous text. Introductory students in Computer Science have a hard time listening to lectures and reading textbooks because if the material is explained in a vague and ambiguous way, it is impossible for them to fully understand the concept being taught [3]. Even if they read the textbook and review the lectures many times, it is easy to forget the material because if they only memorize it and not apply what was learned, it defeats the purpose of learning the material in the first place. This passive form of teaching disengages the students interest on this subject because it encourages them to have the mindset that Computer Science is just a complex and boring subject that only geniuses can understand. One of the ways to resolve this learning deficiency is to use a hands on visual and exercise approach to help students better grasp the material.

There are many visual and hands on learning materials such as YouTube, Khan's Academy, online games, and in class exercises. Online video streaming services such as YouTube and Khan's Academy help students visualize the material in an easier format without having to memorize complex terms and listen to dry lectures [4][15]. Playing online games and working on in class exercises helps students understand the material hands on by working through the algorithm with some guidance [5][10][11][12][14]. The benefit about working on these exercises is that students do practice and apply the concepts presented. However, if students do not get enough practice and/or fully understand the concept, it becomes ineffective since the point of using exercise problems is to apply what was learned in class to a particular problem. Even though, these visual and hands on approaches are an improvement to the traditional lecture and textbook method, another approach that produces better results is to allow students to interact with each other.

Another trending way to help students learn the material is to use Kinesthetic Learning Activities (KLA) [17]. KLA involves all students to participate in class and interact with their classmates. What makes this activity useful is that all students would have to participate by following the instructions outlined by the professor and/or student who is conducting the activity. This active approach allows students to learn the material in a fun and interactive way. Even though KLA allows students to actively learn the material, there are some limitations that prevents them from reaching its full potential.

The problem with KLA is that if the class activity is not properly planned, it not only wastes class time but also ineffectively help students learn. Some shortcomings of KLA includes non-participating students spacing out in class, presenting vague and incomprehensible instructions

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for students who are new to the subject, and not having a coordinator to guide the students when they are stuck. These shortcomings hinder traditional KLA from reaching its full potential because if students do not participate and fully understand what was being taught, it defeats the purpose of using KLA to teach the material [13]. When students want to rerun the activity for more practice, they would always have to depend on the coordinator for instructions.

In order to address the limitations of applying KLA in computer science education, we propose to use mobile applications to assist and support the KLA process. We found that using a mobile device helps students understand how a particular algorithm works by guiding them through the steps to take when a coordinator is not there to guide them. By using KLA with mobile devices, students are not only exposed with using technology but also fully participate in class instead of going through the motions while still being confused on how a particular algorithm works. Non-Participating students can also look at the in class dashboard online to look at every step that was taken to better understand the concept presented.

In this research, we investigate how mobile devices could be integrated with KLA process to provide an effective solution compared to the pure KLA approaches for students. Based on our teaching experience with KLA in classroom, a set of case studies were identified on why we need KLA with mobile devices to help students learn the material. With the fully implemented mobile applications, we conducted experiments on how these applications could be applied with KLA in these case studies to improve the student learning experience and outcomes. After each student has participated in the activities, we present a set of results and feedback to help better understand the effectiveness of KLA with mobile devices in comparison to traditional KLA. The main objective of this KLA with mobile approach is to improve the effectiveness and efficiency of traditional KLA by having students conduct the activity themselves with guidance from the mobile applications.

The remainder of the paper is organized as follows. In Section 2, we provide some motivating examples and list the shortcomings of traditional KLA. Then we present our solution in Section 3 where we discuss how to incorporate mobile devices for KLA. We then analyze related works on how mobile devices are used for CS education and some similar activities in Section 4. Finally, we conclude this paper while providing some insight on future work for using mobile devices for KLA in Section 5.

2. MOTIVATING EXAMPLES

There are a variety of Kinesthetic Learning Activities used in introductory to advanced CS courses. Some topics include basic programming, sorting algorithms, distributed computing, binary conversion, and basic CS concepts. In this section, we look at three different examples commonly used for KLA in class and discuss the shortcomings on each of the activities along with our proposed solution.

2.1 Common Kinesthetic Learning Activities

Switch Statement. For introductory programming classes, students learn how to use *Switch Statements*. This involves a number of set cases where if the item matches the given solution, it would execute only that part of the code along with the other cases if there is no break in the case statements.

Figure 1: Students Running KLA in Class [6]

Should the cases not match the given variable, it would defer to the default solution. What makes it different from the traditional if-else statements is that *Switch Statements* are much cleaner and easier to read for conditions that do not involve number boundaries (e.g., if x $<$ 5 else if x $>=$ 5 && $<$ 10). How to use KLA to teach this concept in class is that we select a group of students would represent the set of case statements, and the student who represents the variable would select which case matches the variable and the student with the case statement would raise it up and see what the case statement does. This method is effective because it allows the students to understand how *Switch Statements* work by creating their own cases and have a specific action to demonstrate its use case.

Quicksort. Quicksort is a very popular sorting algorithm taught in introduction to algorithm courses. What makes this useful for in class KLA is that students can sort themselves based on height without using materials. The flow of this activity involves students putting themselves in random order and setting the middle student as the pivot. The algorithm starts by comparing the first student on the left with the pivot. If the student on the left is shorter than the pivot then it stays at its current position and the left pointer keeps moving until it reaches the pivot. If the student is taller, then the left pointer stops and the right pointer starts with the student on the right. If the student on the right is shorter than the pivot it swaps with the student on the left who is the left pivot. The left and right pointers move until the right pointer and left pointer cross the pivot. The algorithm then repeats itself until all students are sorted from shortest to tallest. By using this method, students can learn that the *Quicksort* algorithm can be applied to many different ordering situations other than numbers.

Decimal to Binary Conversion. Computers understand instructions in only 0s and 1s. The purpose of teaching *Decimal to Binary Conversion* is to give students a basic understanding on how computers calculate numbers and to prepare them for Computer Architecture and/or Embedded programming courses. For the Decimal to Binary KLA, it involves 8 students and each of them would order themselves in the order of 128, 64, 32, 16, 8, 4, 2, and 1 respectively. For a given decimal number to convert, each student would raise their hand if their binary value adds up to the corresponding number. For Example, if the number is 55, the students with bit 32, 16, 4, 2, 1 would raise their hands with the correct bit values and the correct binary number would be 00110111.

Students watching the activity would work the solution on a separate piece of paper and compare it with the result. If the instructor believes the solution is correct, students continue the activity. If it is incorrect, students work out the solution and fix the error to the correct solution before they move on. This approach allows students to see how decimal numbers are converted to binary.

2.2 Pitfalls and Shortcomings of KLA

While traditional KLA can be beneficial for getting students to participate in class and learn the material, there are many pitfalls and shortcomings that prevent them from reaching its full potential. Some examples include non-participating students spacing out in class, coordinator presenting vague and confusing instructions for students to follow, and not being able to help students when they are stuck. As a result, it defeats the purpose of using KLA to help students learn the material. Here are the reasons why traditional KLA might be detrimental to a students success.

Non-Participating Students. When the students are not participating in the activity, they are expected to pay attention to learn the material to see how the activity works. Most of the time, students usually space out when they get confused and when it is their turn, they are clueless on what to do. As a result, class time is wasted and students just go through the motions to run the activity.

Teaching *Switch Statements* using KLA methods can be fun for students. The main problem is that given the simpleness of understanding the subject, students who are observing the activity will not pay attention in class. This is a major problem because non-participating students should also be contributing by checking if the student is doing the activity correctly. When students want to use it for more practice, they would have to write new cases, which wastes a lot of paper. By using the same cases to practice, it already defeats the purpose because students already know the answer to the concepts. As a result, students get stuck when they practice difficult cases when *Switch Statements* do not have breaks.

Presenting Vague Instructions. Giving clear and concise instructions is important to guiding the student on how to conduct KLA. Without it, students will have a hard time understanding how the activity works and not learn anything from it. Usually an instructor or team coordinator will use their method based on their knowledge to run the activity. However, their method of guidance is likely not to be a fit for everyone.

There are many ways to convert numbers from Decimal to Binary. For KLA, students would have to add the bit numbers an see which ones add up to the specified decimal value. This involves a lot of trial and error. With students new to the subject, a lot of time is wasted and non-participating students who are unfamiliar with the subject also have a hard time understanding how to write down numbers in binary. By wasting too much class time on giving clear instructions and doing trial and error, students are better off learning *Decimal to Binary Conversion* on their own.

Getting help when needed. When the student is still stuck and does not understand the concept being taught, the instructor or coordinator can help them resolve any issues they have in class or during office hours. The problem is that when the students are on their own, they have to still rely on the textbook, lecture notes, and other peers during a group study session. As a result, it is pointless to do KLA if the students do not learn anything from it.

When conducting the *Quicksort* algorithm by height, students order themselves by selecting a random pivot and all the students who are shorter than the pivot move to the left and the student who is taller move to the right. They repeat this algorithm until all the students are sorted in height order from shortest to tallest. This activity can also be done vice versa. The problem with using this method is that it confuses the student on how the actual *Quicksort* algorithm works. Since there are many variations of doing *Quicksort*, students have a problem understanding which algorithm is the best one to follow. Therefore, it becomes pointless to use KLA if students start doing the activity without following the exact steps on how *Quicksort* works.

With all these major pitfalls and shortcomings of KLA, it becomes a debate whether or if the instructor wants to use it for class. Some students find it beneficial because it allows them to be more active in learning the material. Therefore, we discuss our solution by incorporating mobile applications for KLA.

3. SOLUTION

In order to address these shortcomings and improve the effectiveness of KLA, we propose a new approach to show how KLA can be enhanced by incorporating it with a mobile application.

3.1 Overview

The mobile application involves guiding participating students through each step of the activity and provides a main dashboard for non-participating students to look at on their laptop, mobile phone, tablet, etc. With the mobile app and in class dashboard shown on the activity website, it allows the students to pay attention in class and understand the concept better by seeing how each step is crucial during the activity. This approach not only allows students to interact with technology but also lets them reuse the program for more practice with many different cases. That way students can practice with randomly generated cases and on their own time. Students would have better control on what numbers, variables, and situations to practice so that they can learn the material in an effective way without a set of fixed cases. Since many courses are incorporating mobile devices into their curriculum, using it for KLA allows students to get exposed to technology rather than solely rely on paper and pencil.

3.2 Technical Implementation

The KLA Mobile app involves two main users: the student and the activity coordinator (can be another student, professor, and/or teaching assistant). The flow of the application starts with the coordinator logging in as the administrator and generating a session code for students to login. Once the code is generated, students log on to the main page by selecting student and entering their name and the code to gain access to the activity. After all the students are entered, they are organized into small groups (no more than 8) so that it is easier to coordinate. Students then run the activity with the guidance of the mobile app and the coordinator. After the activity is completed, students can run the activity again for more practice or end the activity. Once the activity is completed, students are directed to complete

a survey to share their experience and determine the effectiveness of the mobile KLA versus traditional pen and paper KLA methods.

Some technical implementation of the KLA app is that this is a cross platform mobile app which uses HTML5, CSS3 and Bootstrap for the client side UI design. The server side uses Firebase [9] which is a cloud based database and back end system and AngularJS [8] is used for the connection and data binding between the client and server. The front end of this application shows the basic login and form entry, a dashboard which shows the current status of the activity for non-participating students, and a page on the mobile phone for participating students to interact with the application to the activity. The Firebase backend involves storing the student data for each activity, getting a list of the students names, current activity, and the 4 digit code required for entry. Firebase is a cloud based backend utility which stores the data in a JSON format and it allows data binding by the use of the AngularFire [7] which is a library for AngularJS to data bind the connection between Firebase and the Client side. AngularJS also checks for user response and helps simulate the interaction between the dashboard and the user. That way students can learn via technology by having the case presented to them and also guiding them throughout the activity.

The way this mobile and cloud architecture works is that the student logs into the URL link which is hosted on Firebase and it can be accessed on any mobile or tablet device which makes it easier for students who are either using Android, iOS, or any other mobile operating system. When the student logs into the mobile app, it stores their name and validates their 4 digit code matched and generated on the application and stored into Firebase. Once it is successful, students are directed to a page where they stand by until all 8 students login to the app and the activity is chosen. The activity starts once the app name is stored on Firebase. During the class activity, AngularJS and Firebase interact with each other by using 2 way binding to manage and display the data live without having to reload each time when a data gets updated helping students run the application.

3.3 Solution in Action

During KLA, the mobile app will guide the students step by step on what to do. This helps students on knowing how to do each step when it is their turn and non-participating students can see how each step is done via dashboard. When students use it for more practice, they can try out different cases and variables. In this section, we look at how our mobile app solution effectively guides the student through the *Decimal to Binary Conversion* problem from start to finish.

With *Decimal to Binary Conversion*, eight students line up in binary bit positions in descending order from 128, 64, 32, 16, 8, 4, 2, 1. Then the number they have to convert is shown on both the mobile phone and the in class dashboard. Starting with the first student, the student selects yes or no if the binary result adds to the correct decimal value as shown in Figure 2. Once the student enters the result, the bit flips from 0 to 1 on the dashboard. After that, the next student enters their responses and the process is repeated until the final student enters the result. After all the students enter their results, the dashboard shows the final result accordingly. If the result is correct, the dashboard will display "CORRECT" below the 0 and 1 values as shown in Figure 3. It the result is not correct, it will display "INCORRECT" and the students in class have to guide the participating students to the correct answer. With the mobile app, it can generate random numbers from 0 to 255 for students to practice with so that it is much easier to practice many different cases. While *Decimal to Binary Conversion* help students understand how Binary numbers work, common topics such as *Quicksort* and *Switch Statements* are also taught in many CS courses.

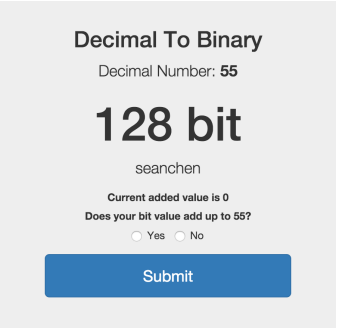

Figure 2: Student View of the Mobile KLA App

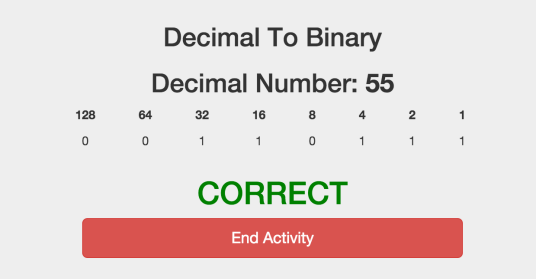

Figure 3: Dashboard View for Non-Participating Students

By following the same type of user interface and user experience implemented for *Decimal to Binary Conversion* application, we also plan to develop the applications to support the other two applications as designed below.

For the *Quicksort* application, when the student selects yes or no for greater than pivot, the result gets sent to the database and it updates accordingly to the result and allows the next student to determine whether or not if they are greater or less than the pivot. If the left and right pivots stop the students swap as long as the pointers do not cross. Once the students swap places, the app checks the current order with the database and if it matches the result is shown on the dashboard. The students run the activity until all elements are sorted. With KLA *Quicksort* as a mobile app, students can better guide themselves by running the activity without any issues

For *Switch Statements*, how it works is that one student is the variable and the rest of the students are case statements while one is the default statement. The student with the variable have to ask each case student if they match and if so they select the result and the dashboard highlights the correct and incorrect results. If none of the cases match, then the student selects the default statement. By using

the dashboard to show students the results, they can have a better understanding on how the *Switch Statements* work without any confusion of paper.

By incorporating mobile apps with KLA, students are able to use technology to help better guide them through KLA. Since many apps help students learn the material via user interaction, it would be beneficial to have a mobile app that can guide students for KLA. Once the KLA is completed, participating students are directed to a link to complete the evaluation on how the mobile KLA worked for them.

4. EVALUATION

The mobile application has been designed and implemented to address the challenges summarized in Section 2. In this section, we briefly talk about how the proposed mobile application can be a complement to the KLA experience in CS education, followed by listing the initial evaluation result gained from an introductory computer science class.

4.1 Addressing the KLA Challenges

By implementing the mobile application for KLA, students are motivated to participate in class and learn the material effectively. The dashboard allows non-participating students to see what is going on in class and observing how the activity works. It also allows the coordinator to see if the students are doing the activity correctly. This helps resolve the issue by having everyone participate and learning how the activity works so that when it is their turn, they know what to do. When the students participate in the activity, the mobile application from the student view helps and guides them on what next steps to take. That way the activity can run smoothly without any vague or confusing instructions. When students want to practice on their own, it would be convenient because one of the students can be the coordinator and the others can run the activity. That way everyone can take turns and practice the activities outside of class without having to depend on the instructor for guidance. In the next section, we look at the evaluation on how students respond to this learning method.

4.2 Experiment in Class

With the developed prototype of *Decimal to Binary Conversion*, we have conducted a small-scale experiment with an introductory CS 101 class in our institution to test the app, as well as collecting the initial feedback from students. The class has 20 students enrolled, with 18 of them being present during the experiment. The students were asked to perform the KLA to learn the decimal to binary concept with the mobile application guided. After all students have completed the activity, the app will be directed to Survey Monkey where they take a survey to evaluate the effectiveness of KLA with mobile. Table 1 shows the initial set of the result from students. As the result shows, students are extremely interested in this new type of learning experience. Almost everyone gave positive feedback. During the experiment, we could clearly see that students are particularly interested in using their smart phones for in-class learning process.

5. RELATED WORK

While KLA is a relatively new field, not many Computer Science instructors have used this method to teach students. The reason being is that many instructors still prefer to use traditional methods to teach students. By doing so, it reduces the amount of extra work to prepare class activities. That way instructors can teach the material using whatever method they are comfortable with. What makes KLA different from traditional learning is that it uses a hands on interactive approach to help students learn the material. For this section, we look at some related works on how KLA and similar interactive interactive learning approaches are used to teach Computer Science concepts.

CS 0 is a common introductory course for students who are new to CS and/or interested in learning basic programming [1]. This course allows students to learn various CS concepts through games, activities, and contests. Games such as Boolean logic helps students understand how basic logic works with these logical values (and, or, not) [1]. Crossword puzzles allows students to learn basic terms needed for fundamental CS knowledge interactively [1]. Activities such as writing instructions on how to make a peanut butter jelly sandwich lets students know how computers follow specific instructions given [2]. The playdough activity shows how object oriented programing works by using the cookie cutter as a class to create objects with playdough [1]. Design contests using Alice allows students to use a basic programming tool to create a scene based on the objects in the gallery [1]. By using this interactive method to teach students, it allows the student to develop their thought process and CS fundamentals through the use of games and in class activities. Even with advanced CS topics, interactive learning such as KLA is useful for distributed algorithm courses.

To make Distributed Algorithms an interesting subject, KLA is used to help students understand the material by having them act as processors or data [13]. Using this method helps students understand how these algorithms work assertionally rather than operationally [13]. Some of the example activities include Nondeterministic Sorting, Parallel Garbage Collection, and Leader Election [13]. For Nondeterministic Sorting, students are represented as an array and that their objective is to use the algorithm to sort themselves until all the values are ordered. With Parallel Garbage Collection, students are in groups of 15 to 20 and they are represented as vertices's in the graph [13]. The objective of this activity is to distinguish which nodes are food and garbage so that the latter is deleted [13]. For Leader Election, students are represented as nodes and each of them connect with their neighboring nodes to keep each process running by keeping the values stable in an event of corruption [13]. These activities teach the various examples on the basic topics of Distributed Algorithms. With mobile phones having the capability to run multiple processors, it might even be useful for daily tasks such as programming.

Usually when students needed to write computer programs, they would need to carry a laptop with them at all times. In the old days, it was hard to access a computer because most of them were desktop based. Today many people using mobile devices, which makes it easier to access information. TouchDevelop was created to help students learn how to program on their mobile phones so they can use it for more practice without having to carry their laptop at all times [16]. Students can also use it to create mobile apps to show their friends on what they created. This helps students spend more time on the logical development of the program rather than spending time writing syntax that easily leads

Question	Yes	No	Hard to Say
Would you say the mobile KLA you done today was helpful in learning the material?	18	0	0
Do you think KLA with mobile is useful for class activities?	18	0	0
Would you say KLA with mobile is better than traditional KLA?	17	0	1
Would you consider using KLA with mobile for future CS courses?	18	0	0
Would you recommend KLA with mobile to others?	17	0	1

Table 1: The survey questions and result collected from a class experiment.

into ambiguous typos. While TouchDevelop is useful to help students with programming on mobile phones, incorporating our mobile device with KLA can make the activity transition better by guiding the students through each step [16].

With all the different interactive methods used to teach students various CS topics, our idea is to integrate mobile devices for KLA. Since Traditional KLA is mostly paper and pencil based, accompaniment them with a mobile app allows better guidance for students who are new to the subject. With the mobile app, many cases are randomly generated and students can practice it many times without having to spend time creating the props needed to run the activities. This helps alleviate the planning process needed to run the activities and allow the students to interact with technology better.

6. CONCLUSION AND FUTURE WORK

In this paper, our objective is to improve the effectiveness of KLA by incorporating mobile applications so that all students can learn the material interactively. Traditional KLA helps students interact and learn the material. However, it would be much more beneficial if it can be incorporated with a mobile app that can guide students to run the activity. For this research, a mobile based web app is created to help students run KLA and allow non-participating students to see how each step is ran. Many related works look at how professors use unconventional methods to teach students various CS concepts and how to apply them in real world situations. For future work, we would make this app a tool for all KLA and allow this project to be open source where developers can contribute their KLA to make it more mobile web app based. That way all students can learn various CS concepts interactively through the use of mobile apps and KLA.

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