Building an Interactive Mobile Application to Enhance Students' Problem Solving Skills in Higher Education Physics

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Abstract: Problem solving is a major part of the learning process that students need to acquire in their university education as it combines several skills within, such as comprehension, memory recall, critical thinking, and mathematical skills. Even though instructors and students recognize the importance of problem solving, generally both groups fail to culminate this corner step in the learning process. Students fail to realize that it is not the final answer of an assignment that is the important outcome, but rather the learning process and skills that are gained through problem solving. Technology and mobile applications can harvest the students' attention in the process of problem solving and make them more willing to learn. We discuss the case of building an interactive mobile application that fosters the major steps in problem solving. The application is built to guide, help, encourage, motivate the students, and create a more interactive and exciting environment. It is built on an algorithm that relies on the major steps of problem solving. The first version of the mobile (Android) application is produced.

1 INTRODUCTION

Problem solving in the education field of science & engineering is an indispensable part of the learning process that students need to acquire in their university education, (see (Gabel, 1994), (Ramsden, 2003), and references therein). Almost all undergraduate programs in university setting list problem solving skills and critical thinking as a major program learning outcome. Most of science and engineering courses include the same item in their course learning outcomes.

Definition of problem solving process varies in the literature, for example according to (Ausubel, 1963), problem solving is a form of discovery learning. While (Gagne, 1970) views the process as assembling rules to create a new superior rule that allows a solution. The process can also be viewed as a cognitive process directed as achieving a goal when no solution is obvious (Mayer, 1992). Students face considerable difficulty in the process of problem solving for several reasons; such as lack of understanding the basic concepts and lacking the appropriate knowledge structure related to a specific content (Nakhleh, 1993).

Literature on the issue of problem solving identifies few major steps in the process of learning (Fraser and Butts, 1982), (Greeno, 1973), (Polya, 1945), (Simon, 1980). With few differences between different viewpoints in literature, we can identify the following major steps that are contained in the process; understanding the language structure of the problem (especially important for students with English as a second language), defining the problem and being able to recognize its elements, selecting the appropriate information, being able to make some prediction beforehand, constructing a solution plan, implementation and evaluation. During this process, students are expected to face challenge and many students easily quit and run for the short exit.

Even though instructors and students recognize the importance of problem solving; generally, both groups fail to build on this corner step in the learning process. For students the process is difficult, confusing, and challenging. Critical thinking is not acquired by students in schools and it is considered a highly challenging and time consuming process.

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Math skills are generally weak and not integrated well in the learning process. In many cases, students fail to understand the details of the problem they want to solve and are unable to link it to their shaky understanding of the class material, not to mention the insufficient mathematical skills students have. For educators, lack of time and large number of students force the problem solving part to be minimized. Educators rely on traditional assigned homework but this rarely builds the critical thinking and other important skills. From our experience, students consider homework a burden to be submitted with minimum effort. Some students rely on plagiarism, copy assignment from other students, or simply perform a messy mathematical manipulation to produce the required final numerical answer of a problem. Students fail to realize that it is not the final answer of the problem that is the important outcome of the assignment, but rather the learning process, the critical thinking, and other skills that are gained through problem solving. On the other hand, educators do not spend enough time on this part of learning due to lengthy content and large number of students. Many instructors feel very skeptic about students' effort in problem solving. Sadly, the claim that college education aims at fostering critical thinking skills turns out to have little ground proof. Research on the different aspects of problem solving in science is abundant in literature, examples include (Larkin, 1979), (Stewart, 1982), (Woods, 1975), (Ferreira and Trudel, 2012), (Duch,1996), (Fuller,1982).

We believe that technology and mobile applications can harvest the students' attraction and attention in the process of problem solving (see (Martin-Blas, 2009), (Childress, 1996) and references therein). Technology motivates students become more receptive and even more willing to participate in learning (Kim and Hannafin, 2011), (Shurygin et al., 2016), (Walker and Shelton, 2008). Technology has already found its place in education for young learners (Papadakis and Kalogiannakis, 2017) and higher education (Kikilias et al, 2009), (Papadakis et al, 2017) with several existing platforms, solutions, and applications. Available solutions can be divided into two groups; Comprehensive Educational platforms and stand-alone applications:

The Comprehensive Educational Platforms includes but not restricted to Blackboard, Desire to Learn, Moodle, and Masteringphysics. Those platforms are based on a Learning Management System (LMS). LMS allows instructors to carry out learning activities, make announcements and assess student work. LMSs store and deliver materials developed in a variety of different formats. They support interactions between faculty and students. Online learning management systems can be hosted locally or remotely. On those powerful platforms students can access resources online, solve questions, exercises, and problems with the ability to browser through textbooks, videos, conceptual pre-lectures, and other material and hints. New features are added regularly as publishing companies invest heavily in such applications. United Arab Emirates University, our institution, is already using Blackboard and Masteringphysics.

LMS platforms are very powerful and the only limitation we have experienced is regarding guided problem solving. Many instructors rely on those platforms to generate simple exercises, multiple-choice questions, true-false questions, and so on. Those platforms offer students a small window to enter equations and their final answers. For the more involved problems such platforms remain of little use and value as they are missing on the important feature of enhancing and guiding the critical thinking process itself. As stressed before it is not the final answer that is the goal, rather it is shaping the critical thinking skills of students. Therefore, those platforms are still short of value for problem solving as they lack interactive personalized support and guidance. Our proposed application can make an important addition to those platforms as it can fill the gap we are experiencing in problem solving skills.

There are few stand-alone applications of physics including but not limited to Physics Solver, Learn Physics, Visual Physics, Physical Mechanical problems. However, existing stand-alone mobile applications in the market are of little value. They are simply performing as a calculator aiming at calculating a number to one of the most used equations in physics or mathematics. Some applications are offering explanations to various topics but all lack an interactive guided support in problem solving. Such applications provide minor value to the process of critical thinking and problem solving in general.

In this paper, we discuss the case of building an interactive mobile application based on an algorithm that relies on the major steps of problem solving. The application should serve to guide, help, encourage, and motivate students. The application should create a more interactive and exciting environment for students. This mobile application should foster the problem solving skill among students and create a supportive environment for critical thinking. This application is not a type of calculator or plugin tool to find a final numerical value; rather it is a guide for

students to utilize and improve the thinking process and their strategies to solve challenge problems. It will encourage students to reflect on their approach and will provide a help connection with their instructors. Later, the application will be tested on a sample of students and based on results; a plan to upgrade the first version to include more capabilities could be performed. The application will link students with their instructor at the major obstacles students face, allowing for real time interaction. In addition, the application should be able to save students interactive history and allow instructor to browse through and give feedback. This application will be of important addition to education technology as it lacks such product.

2 METHODOLOGY AND FRAMEWORK

The major step in creating this application is to build an algorithm that can guide and support students in the process of problem solving. The algorithm does not provide direct solution to problems that students want to solve, but rather it provides guidance, support, and opportunity to reflect on the major sub steps of the whole process. The algorithm also directs students for help and support in situations where a student is stuck or unable to proceed to the next step. The algorithm is implemented as a mobile application that gives students a personal guide and support during the problem solving process. We produce a simple first version with has direct features that tackle the major cornerstones of the problem solving process. The important features of the application are listed below:

1) An administrator is required to monitor and control the application use (to be implemented in higher versions).
2) The application is built based on the major corner steps of problem solving according to faculty experience, literature, and students' feedback.
3) The application creates an interactive and exciting environment for students. We expect students become more receptive and even more willing to learn.
4) It aims at attracting students to use and link the process of problem solving with their instructor, allowing for real time interaction. Students can send questions and request meeting with their instructor. Group discussion and chatting among students, enrolled in the same course (to be implemented in higher versions).
5) The application should provide clear advice and start with a famous encouraging quote to keep student enthusiastic and encouraged.
6) The application will link to valuable resources on the internet, such as dictionaries, youtube, and other free resources.
7) The application will not solve assigned problems for students; however, it aims at enhancing the students' critical thinking and all related skills.
8) The application will suggest possible hints for students once stuck at a given step. It may direct students for additional help from the internet or from their instructor.
9) The application will guide the students to reflect at each major step of the problem-solving process. It will ask students to comment and answer few directed questions before moving to the next step.
10) The application can save students interactive history and allow instructor to browse through, thus instructors can monitor students' progress. Instructor's feedback is also possible (to be implemented in higher versions).
11) The application should be of a valuable addition to the current education technology. The current education market lacks such innovation and the hope is to succeed in convincing students and educators to implement the use of such product. The real success of the project will come from the apparent help this tool will provide in the learning process of physics and science in general.
12) The first version will be tested on group of students and based on results; an upgraded version incorporating more features can be developed.

The application is to be constructed based on 7 major parts. The first three parts will be implemented in later versions; namely, Part I (Create Profile), Part II (Create/Join Class), and Part III (Create Assignment). These parts are technical and will handled later. In fact, these parts could be integrated with the Blackboard platform already used at UAEU. The other four important parts are discussed below.

2.1 Comprehension Part

This is the most important part especially for English as second language students. Students start problem solving with this part. Student will view first problem only. They will need later to request viewing next problems. Students start this part by reading the first problem carefully and slowly for several times, then they are asked to highlight/type important words and other irrelevant words with justification. Next students will specify any word/phrase they do not understand and then will be directed to dictionary,

internet, textbook, notes, or seek help from other students. A similar step for any sentence they do not understand and seeking possible help from instructor. Students are encouraged to picture the problem in their head and think of all its details. This part is very important before they move to the next part, as it aims to foster language and contextual structure of the problem. With sufficient practice, students will acquire the skill to fluently comprehend the language structure of given problems in their textbooks and exams. A flowchart of this part is provided below in Figure 1.

2.2 Analysis Part

This part is also very important before students actually start solving the problem. Students should spend enough time to think about each part of the question and what it requires, Students are asked to summarize the question in a short sentence and in their own words. Students are asked to explain the question to other peers. This part aims at preparing the student to be confident in understanding the question. Students should not move to the next part until they feel confident they understand the question. Students are reminded that understanding a problem constitutes a big part of finding a solution. A flowchart of this part is also provided below in Figure 2.

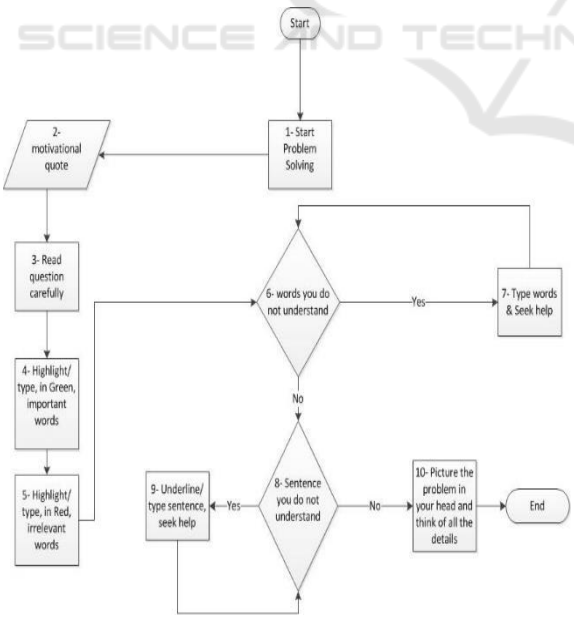

Figure 1: The comprehension Part.

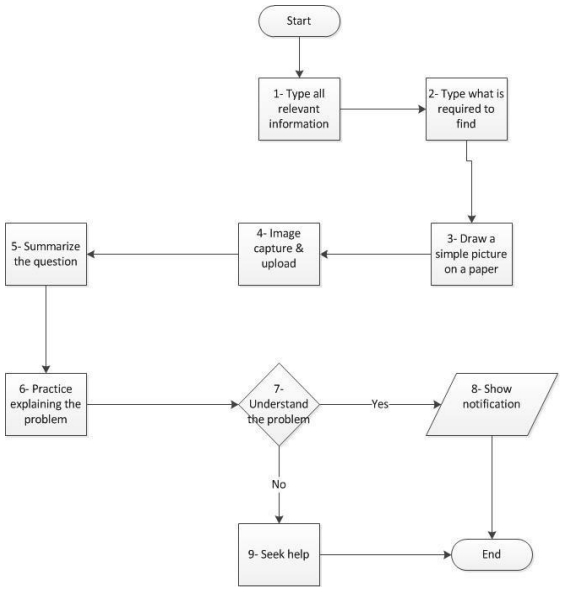

Figure 2: The Analysis Part.

2.3 Solving Part

In this part students plan their solution and reflect at each step. This part aim at improving mathematical and organization skills. Students make a plan for solution and then follow through. Once stuck, students are encouraged to rethink about the problem and seek help from instructor. The application does not solve the problem but it encourages the students to think about their solving strategy. Students are reminded that it is not only the final answer that they are looking for, but rather the whole learning process. We show below very few lines of the computer source code written for this part.

```
    <!-- Place new controls here -->
    <Image Source="q1.png" />
    <StackLayout Padding="0,20,0,0">
    <Label Text="Comprehension Part 1"
    HorizontalOptions="Center"
    VerticalOptions="Center"
    TextColor="Black"
    BackgroundColor="LightGray"
    Style="{DynamicResource
TitleStyle}"/>
    </StackLayout>
    <Label Text="Read the first problem
carefully and slowly at least 2 times,
then click NEXT"
    LineBreakMode="WordWrap"
```

2.4 Evaluation Part

This is the last part where students reflect on the pro-

cess of problem solving. Students are asked to check their solution for correct dimensions and compare it with the correct answer, if given. Students are asked to make sense of their final answer. This part forces students to think about the validity of the solution and check their understanding. Students rate the application at the end of the process. A flowchart of this part is not shown but is available and has been implemented in the source code.

This is the end of the proposed algorithm for the application with specific details on each step. The source code has been written in JavaScript as Android application. The source writing has been mainly done by students coauthoring this project. Currently all parts of the application have been completed except the first few technical parts which should be done once adequate technical support is available. The application was created with the aim at helping students during the process of problem solving offering guidance and support. It provides a companion for students to rely on in the process of critical thinking and helping in acquiring problem solving skills. The application should be tested later on a group of students; it can be updated based on students' feedback and instructors' feedback too.

3 CONCLUSIONS

This project was initiated as an undergraduate research project at UAEU. The importance of the application stems from the observed struggle that students face in problem solving. We aim at helping and guiding students through the problem-solving process through a mobile application, that may trigger interest among students. Through literature review and based on our own experience we divided the process of problem solving into several parts that students need to go through. A flow chart for each process has been developed. Next the non-technical parts of the flow charts have been written in a JavaScript to initially generate an Android-based mobile application. Since the project has been developed by undergraduate students, few technical parts have been postponed till adequate technical support is available. The application has been named "Physible" and the first version is at its final stage. The application should be available on Google Play Store within one month. We plan to test the application next fall semester at UAEU on a group of students in multi-sections introductory physics course. We plan to use the application on few sections in the course while other sections will keep using the same methodology. By analyzing grades of problem solving part of assessment and through developed surveys of students and faculty members, we will test the application and its benefits. We claim that the application will enhance students grades and improve attitudes and motivation toward learning physics, such claim will be tested next fall semester. Results on using the application will be then presented and hopefully we can test our claims. Based on testing the application and feedback from students and instructors we plan to upgrade the application to include more capabilities. The Logo of the application is show below in Figure 3. In addition, we show a screenshot of one of the application pages, see Figure 4.

Figure 3: Logo of the Application.

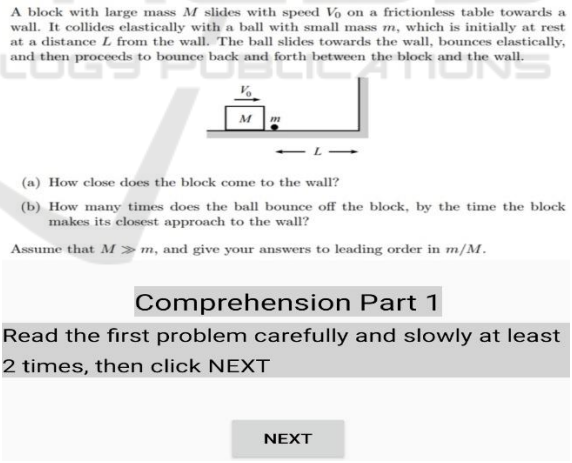

Figure 4: A screen shot of one page of the application.

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