Utilization of the algebraic method in the design and development of the ChemRxnCalc mobile application prototype

Ma. Eliza P. Cruz
College of Arts and Sciences
San Beda University, Manila, Philippines
mcruz@sanbeda.edu.ph

Jake M. Libed
College of Arts and Sciences
San Beda University, Manila, Philippines
jlibed@sanbeda.edu.ph

Abstract

Responding to the need to create an "equitable learning space" for Chemistry students in the new normal classes, the authors designed a mobile application prototype named ChemRxnCalc. It is intended to help students balance chemical equations by predicting products and their coefficients from given chemical reactants accurately and using the algebraic method. Upon the development of the mobile application prototype for Android mobile phones, it was subjected to an initial validation by eight (8) Chemistry teachers deemed to be the subject-matter experts and which yielded a high usability percentage following the software quality requirements set by the ISO/IEC 25010. It is recommended for second-phase validation by students. This could be accomplished by uploading the e-tool to the RedCanvas learning management system (LMS) of the University. The initial target users are the Senior High School and College Students of San Beda University, Manila, and probably, the Mendiola Consortium who are taking up General Chemistry and/or Inorganic Chemistry. Consequently, once the ChemRxnCalc mobile application prototype has been validated by both experts and students, it is intended to be patented thru registration in the Intellectual Property Office of the Philippines (IPO). It is also targeted to be registered and uploaded in the Google Playstore and Apple Appstore for consumption of a bigger teacher and student population.

Keywords: balancing chemical equations, chemistry e-learning tool, equitable quality education, mobile application prototype

Background of the Study

There could be ways to simplify complex ideas without losing their innate essence. Calaprice (2010) quoted Einstein…" the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience". This is deemed essential in facilitating learning and maximizing student potential. Educators must consistently create opportunities for students to construct meaning on their own. Such aforesaid opportunities must allow them to find patterns, leading them towards their discovery of simple approaches to create and understand the meaning. Such developed skills of creating and understanding meaning will lead them to be effective problem-solvers and not merely solution-absorbers.

In adapting to the new normal in education as brought by the COVID-19 pandemic, teachers are challenged to be flexible in providing students with opportunities to learn. As the UN Sustainable Development Goal 4 mandates, inclusive and equitable quality education must be ensured at all times while at the same time promoting lifelong opportunities for all (UN DESA, 2020). Learning gaps must be filled, opportunities for students to learn must be constantly created, and school stakeholders must consistently take collective action towards resiliency and adaptation.

An obvious learning gap in the teaching and learning of chemistry in the new normal is the limited synchronous interaction between teachers and students and between students, themselves. As the course is laden with abstract concepts that make use of mathematical rules to be understood and with mathematical ability as a known heritable component that is linked to several genes in the brain development, it is expected that students' understanding of the course may be widely vary and which may result into extreme bipolarity in learning. For quality education to be equitable, a supplementing and complementing environment for learning must be created for those who need it. In this case, students who are "barely passing" must be given their much-needed "equitable space" where they could eventually catch up with the rest of the class and meet the course outcomes.

Saberon (2021) utilized the algebraic method in her created E-SCRIBE macros-run (VBA) application using MS Excel. Upon completed ideation and validation of the aforesaid application, she recommended that this same e-tool be converted into a mobile application to increase student and teacher engagement.

Picking up this aforesaid recommendation, the researchers created its equivalent ***ChemRxnCalc*** prototype mobile application initially for Android phones. It is intended to help students in Chemistry in enhancing their skill in balancing Chemical Equations via the Algebraic Method approach. Vazquez (2018) postulated that mathematical models could effectively describe scientific processes and may even be used as a tool to predict relationships and causation. He thought that such aforesaid models could concretize man's understanding of the natural world.

This mobile application is proposed to be the "equitable learning space" in Chemistry that shall address the learning gap previously discussed. It is flexible, with the student being empowered to micro-manage his time of use of the application, while at the same time, easing the difficulty of teachers in lesson delivery as the student may just review and validate what he has learned thru the app during the synchronous classes. Indeed, it showcases resiliency and systematic adaptation to the new normal as it gives a chance to students to identify and work on their learning gaps or difficulties at this time of the new normal while resonating with the intent of promoting equitable learning toward quality education.

Research Objectives

1. Create a mobile application prototype using the Algebraic Method as input, that can predict and balance products of chemical reactions correctly.

2. Subject the mobile application prototype to validation by subject-matter experts.

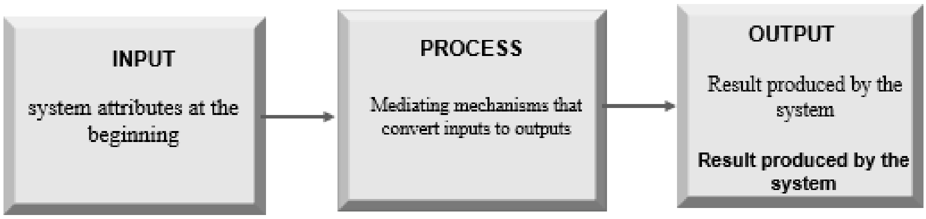
Conceptual Model and Operational Framework

This software development research made use of the Input-Process-Output (IPO) conceptual model. It is a structured approach that identifies goals and objectives of a system and utilizes it to support a gap analysis (MacCuspie and Drake, 2014). Further, it is a widely used approach in systems analysis and software engineering where many programming and analysis texts are introduced and described (Braunschweig, n.d.).

In this context, the algebraic method was used as the input in correctly predicting and estimating the products and coefficients in a chemical reaction. The Kotlin programming language was used as the processing system or the mediating mechanism, with the *ChemRxnCalc* mobile application prototype as the output.

Figure 1.

Steiner's IPO Prinnciple (1972)



The figure below captures the salient features of the IPO conceptual model as applied to this software development research:

Figure 2.

Conceptual Model of the ChemRxnCalc Software Development Research

Input

There are various teaching techniques used in dealing with the topic of Balancing Chemical Equations. *Balancing by Inspection* or commonly known as the *Trial-and-Error Method*, appears to be the most common while *Balancing by Algebraic Method* seems to be the least used (Hamid, 2019). The former, as the conventional teaching method in the topic, balancing chemical equations, could only be used for simple equations henceforth, when equations become complex, students are left confused on how to deal with them correctly. (Gabriel & Onkuwa, 2015).

The idea of the use of the algebraic method in balancing equations was first introduced by Curtis (1922) in his work, "Algebraic Method of Balancing Chemical Equations". He posited that the algebraic method could satisfy the Law of Conservation of Mass, where the number of atoms of the elements present on the reactants' side must be equal to the number of atoms of the elements present on the product's side. He considered this method a convenient approach to balancing complicated equations which cannot be solved by the trial-and-error method.

Likewise, Hamid (2019) exposed in his study that balancing equations by inspection does not systematically produce correct stoichiometric coefficients, thus, could only be applied to simple equations. He furthered that the strength of the algebraic method is that it could provide a systematic evaluation of the stoichiometric coefficients regardless of the complexity of the chemical reactants and products.

In contrast, Charnock (2016) argued that balancing by inspection was suitable for solving both simple and advanced chemical equations that are free from formal chemical charges. However, he agreed that the algebraic method was superior in balancing chemical equations than balancing by inspection. He further clarified that the Algebraic Method is not a new approach to determining stoichiometric coefficients and its effectiveness and efficiency have been established already for a long time.

Process

The mediating mechanism in this research is the Kotlin Programming Language. It is an open-source statically typed programming language that targets the JVM, Android, JavaScript, and Native and which is developed by JetBrains in 2010 (kotlinlang.org, n.d.). It is also supported as a first-class language on Android which makes it the best option in the development of the *ChemRxnCalc* mobile application prototype. Further, as per its official website, it is interoperable with the Java programming language with its major emphasis placed on ensuring that an existing codebase can interact properly with Kotlin. This will mean users could easily call Kotlin code from Java and Java code from Kotlin. This makes adoption much easier and lower risk. There is also an automated Java-to-Kotlin converter built into the IDE that simplifies the migration of existing code.

Output

With the algebraic method as used in balancing chemical equations as input and the Kotlin programming language as the mediating mechanism, the *ChemRxnCalc* mobile application prototype is created. This mobile application prototype acts as a stoichiometric calculator that can predict products and their corresponding coefficients from given chemical reactants accurately.

Operational Framework

The stages in the development of the *ChemRxnCalc* mobile application prototype, on the other end, were patterned after Sutton's stages of descriptive-developmental research (2020). This resulted in this operational framework:

Table 1.

Operational Framework

Stages of Development and Validation	Actions Taken
1. Stage 1- Ideation	Review of relevant studies on electronic teaching tools and algebraic method as used in balancing equations, alongside mobile application prototyping protocols and processes.
2. Stage 2- Planning	Selection of relevant data (both on mobile application prototyping via use of Kotlin programming language and using algebraic rules as grounding data) leading towards selection of data analytic techniques.
3. Stage 3-Prototyping	Creation of *ChemRxnCalc* mobile application prototype
4. Stage 4- Pilot Validation	Pilot validation of the *ChemRxnCalc* mobile application prototype by subject matter experts.

The succeeding section on methodology highlights how these aforesaid operational stages are accomplished in this study.

Methodology

In the development and validation of the ChemRxnCalc mobile application prototype, the features of descriptive developmental research were utilized. Richey (1994) clarified that developmental research is particularly important in the field of instructional technology, especially if intended for product development and evaluation. It may even serve as a valid basis for model construction and theorizing.

Its stages of development, on the other end, were patterned after Sutton (2020). He suggests that these protocols should be observed: ideation, prototyping, and ending with pilot validation, which, in this context, was accomplished by subject matter experts in the person of eight (8) Chemistry teachers.

Stage 1: Ideation

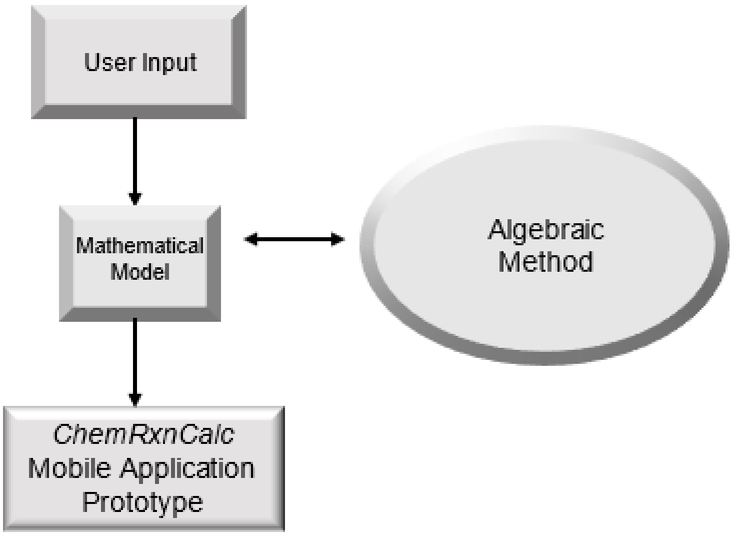
The project commenced with ideation. It is the stage where ideas highlighting balancing equations via the algebraic method was pooled and analyzed. Consequently, this information was used as inputs in an appropriate mediating programming language, which in this case, is the Kotlin program language.

Mobile computing requires lightweight devices such as smartphones, personal digital assistant (PDA) tablets, and laptops. It is a ubiquitous technology that is very much integrated with everyday living (Jayatilleke, 2018). Through easy-to-navigate/ user-friendly mobile applications that could be downloaded thru Google Play Store and iOS App Store and stored on mobile computing devices, users are allowed to simultaneously perform different transactions and functions (Baktha, K. 2017).

Figure 3 below shows the block diagram of the proposed system which starts by asking the user to enter the reactants and products. The next process is the application of the mathematical model, in this case, the Algebraic method, to produce the final output which is the product of the chemical reaction and its correct coefficients, leading toward a balanced chemical equation. After ideation, careful planning on the creation of the prototype followed.

Figure 3.

Block diagram for the ChemRxnCalc mobile application prototype



Stage Two: Prototyping

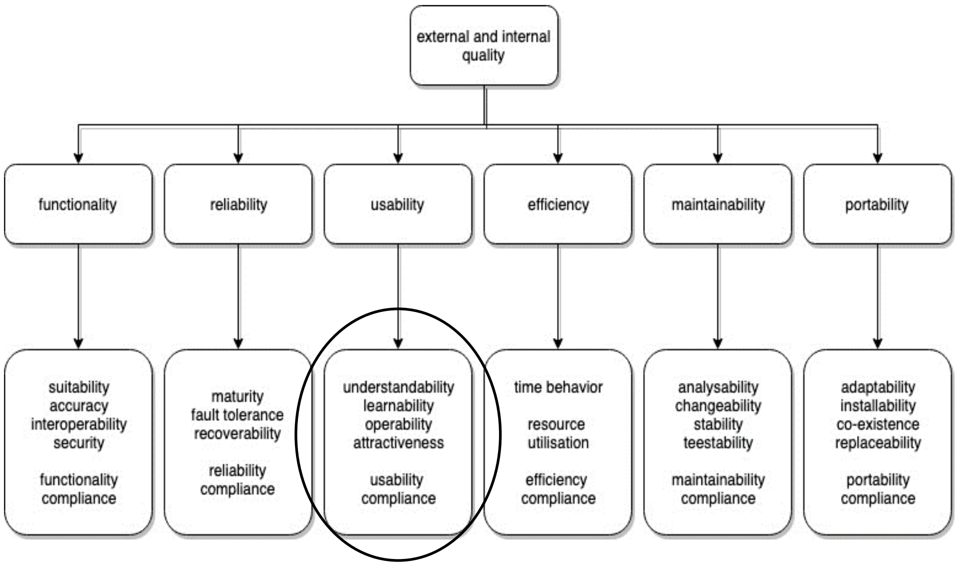
The researchers utilized the Kotlin program language in the creation of the ChemRxnCalc mobile application prototype. Kotlin is a programming language released to the public in February 2016, which in May 2018, was declared by the Google Android team to be the official Program Language for Android development (Bose, 2018). The integrated development environment (IDE), on the other end, was used in the development of the application via the Android Studio. The mobile application prototype was completed sometime in January 2022.

Stage Three: Validation

Upon completion of the prototype, it was subjected to initial validation by eight (8) subject-matter experts/ chemistry teachers using the ISO/IEC 25010 Software Quality Requirements. This quality evaluation system can determine the satisfaction of users in terms of software product quality using eight quality characteristics as shown in the figure below. The prototype was validated via its usability characteristic only.

Figure . 4

*ISO/IEC 25010 Software Quality Requirements (**ISO20500.com**)*



The ISO/IEC 25010 provides consistent parameters and nomenclature for specifying, measuring, and evaluating system and software product quality (Britton, n.d.). It is aptly named Systems and software Quality Requirements and Evaluation (SQuaRE) and consists of eight product quality characteristics and 31 sub-characteristics. These eight product quality characteristics include functional suitability, reliability, performance efficiency, usability, compatibility, maintainability, and portability.

Functional suitability pertains to how well a product or system can provide functions that meet the stated and implied needs. Reliability is on measuring how well a system performs specified functions under specified conditions. Its capacity to perform given a specific number of resources is described to be its Performance efficiency while usability is about how well it could achieve a goal. Security measures its capacity to withstand data security vulnerabilities. Further, compatibility speaks of its ability to function in diverse software and hardware environments, and lastly, maintainability checks how the system can be modified to improve, correct, or adapt to changes in the environment as well as its requirements.

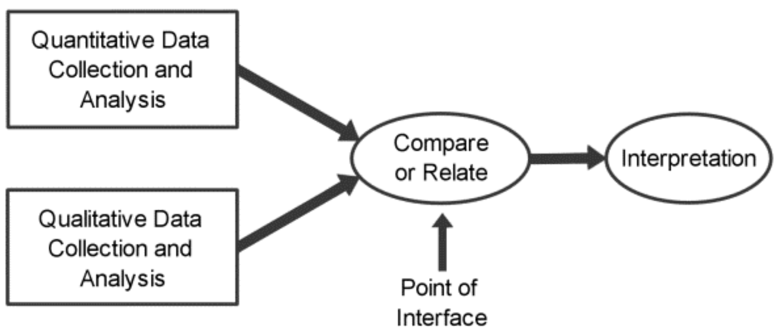
As the validators are all Chemistry teachers, the researchers thought that their expertise would be on determining only if the application can achieve the goal— could it balance chemical equations correctly? Henceforth, only the usability feature was tested for validation. The other characteristics of the ISO/IEC 25010 were not investigated as it will mean needing a new set of validators who are presumably, IT experts.

Research Approach and Procedures

This project made use of the Convergent Parallel Mixed Methods Research Design. Both quantitative and qualitative data were analyzed separately and consequently compared to see if the findings confirm or disconfirm each other. The key assumption of this approach is that both qualitative and quantitative data may provide different types of information that are essential in determining the accuracy of set measures and/ or standards (Creswell, 2014). Qualitative data gathering is needed in the ideation and planning stages of the material development whereas concurrent qualitative and quantitative data gathering were applied in the pilot validation of the ChemRxnCalc mobile application prototype.

Figure 5.

The Convergent Parallel Mixed Methods Research Design (Creswell, Plano, and Clark, 2011)



Population and Sample of the Study

The targeted validators for the ChemRxnCalc mobile application prototype were subject matter experts (SMEs) in the person of eight (8)

Chemistry teachers both in the Basic Education and Higher Education Institutions in the Mendiola Consortium and the Greater Manila Area. They were selected via Snowball Sampling. The latter is an approach where the research participants themselves recruit the other participants for the study (Parker, 2019). The validation of the prototype took a month, from February to March of 2022, to be completed.

Data Analysis Procedures

The researchers made use of descriptive statistics for the quantitative data gathered and thematic analysis for the qualitative feedback.

These quantitative-descriptive measures were used to validate the ChemRxnCalc mobile application prototype:

Frequency Count, Weighted Mean, and Percentage. These reflected the mean scores the selected validators gave the ChemRxnCalc mobile application prototype. Its frequency distribution is deemed to provide a visual representation of the distribution of observations within a particular period.

To interpret the qualitative data that is intended to re-affirm generated quantitative results, thematic analysis was used.

Thematic Content Analysis

Responses of the validators in the quantitative survey were re-affirmed via qualitative data gathering thru interviews. Their qualitative responses were analyzed thru the use of Thematic Content Analysis wherein the researchers identified common themes or patterns in the transcripts with the use of Coding. Coding is a way of indexing or categorizing the text to establish a framework of thematic ideas (Gibbs, 2007).

To analyze the qualitative data, the researchers followed these steps as cited by Braun and Clarke (2019):

1) Read the transcripts thoroughly.
2) Code the data.
3) Identify thematic patterns.
4) Analyze the patterns; and
5) Write the results.

Saturation points of coded data were also systematically exacted.

It was assured that the quantitative results, as revealed by frequency distribution, mean and weighted average, were substantiated by the coded qualitative data generated thru virtual interviews of the subject matter experts in the person of eight (8) Chemistry teachers in the Mendiola Consortium and the greater Manila area.

Research Ethics Approaches

All the necessary protocols in the doing of the ChemRxnCalc mobile application prototype from the letter of request distribution to target validators to the processing of the data gathered were treated with utmost confidentiality and honesty. As this project is limited to the development of an e-tool mobile application that is projected to provide flexible learning material in Chemistry, it is encompassing to note that no animal or human was harmed while the research is ongoing. Further, all requirements of the Research Center and the Research Ethics Board of this University were complied with, promptly and diligently.

Results

Upon completion of the prototype and following the protocols on software quality assurance as set by the ISO/IEC 25010, specifically in the field of usability, the researchers crafted three (3) items in the pilot validation of the ChemRxnCalc mobile application prototype. These were the 3 questionnaire items mapped:

1. The application is easy to use. This is intended to validate its operability.
2. The design of the app is straightforward. This statement is to validate its aesthetics.
3. The result the application generates is correct. This last item measures its user error protection.

Using the 5- point Likert Scale with its verbal interpretations cited below, the generated results of the initial validation reveal a very good reception of the ChemRxnCalc e-tool in terms of operability, aesthetics, and user error protection.

Figure 6.

Likert Scale Rating and Verbal Interpretations

1.00 – 1.49	Strongly Disagree
1.50 – 2.49	Disagree
2.50 – 3.49	Neither/Nor agree
3.50 – 4.49	Agree
4.50 – 5.00	Strongly Agree

Table . 2

Pilot Validation Summary of Results of the ChemRxnCalc Mobile Application Prototype

Total Number of Validators	Item 1 **Operability**	Item 2 **Aesthetics**	Item 3 **User error protection**
N= 8 Chemistry Teachers in College and High School	The application is easy to use.	The design of the app is simple and straightforward.	The result the application generates is correct.
Average	5	4.875	5
Interpretation	**Strongly Agree**	**Strongly Agree**	**Strongly Agree**
Standard Deviation	0	0.35	0

The table above captures the actual recorded responses of the validators.

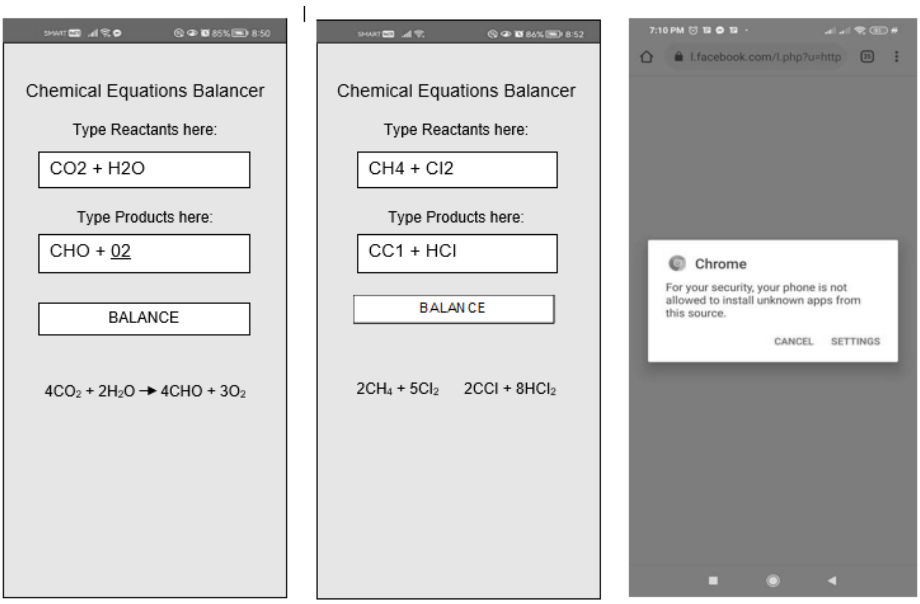
On *operability*, all the eight (8) validators strongly agreed that the *ChemRxnCalc* mobile application prototype is easy to use. Two validators even expressed that even if the products entered by the user are incorrect, the mobile app could still generate or yield the correct products and consequently provide its accurate coefficients, thereby leading to a balanced chemical equation. Simply said, the *ChemRxnCalc* app could even rectify or correct wrong user entries in the product field box.

On *aesthetics*, 7 of 8 strongly agreed that the *ChemRxnCalc* mobile application prototype has a simple and straightforward design. One validator, however, commented on the possible use of a lighter colour for the field boxes where the reactants and products are typed and a darker background to highlight the user field boxes.

In terms of *user error protection*, all validators strongly agreed that that the results generated by the app are correct.

Figure 7.

Some User Screenshots of the ChemRxnCalc Mobile Application Prototype



The generated themes from the follow- up interviews conducted described the user experience of the e-tool as:

1. Refreshing; as it took them a shorter time to balance chemical equations.
2. Good for review; as the user could manually balance the chemical equation and verify its correctness thru the use of the application;

3. Gateway for more flexible e-learning materials; as they think this is the era where there is a need to produce more materials to aid e-learning.

Recommendation

Upon completion of the initial validation of the ChemRxnCalc mobile application prototype by subject-matter experts, it is recommended for second-phase validation by students. This could be accomplished by uploading the e-tool to the RedCanvas learning management system (LMS) of the University. The initial target users are the Senior High School and College Students of San Beda University, Manila, and probably, the Mendiola Consortium who are taking up General Chemistry and/or Inorganic Chemistry.

Consequently, once the ChemRxnCalc mobile application prototype has been validated by both experts and students, it is intended to be patented thru registration in the Intellectual Property Office of the Philippines (IPO). A patent is an exclusive right that allows the creator or inventor to exclude others from making, using, or selling the product of his invention during the life of the patent (IPOPHIL, 2021). By requesting the Grant of Patent for the ChemRxnCalc mobile application prototype from the Intellectual Property Office of the Philippines, it could secure and protect the invented utility model from piracy and unauthorized use.

It is also targeted to be registered and uploaded in the Google Playstore and the future, in the Apple Appstore for consumption by a bigger teacher and student population.

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