

Effects of using mobile augmented reality for simple interest computation in a financial mathematics course (#52967)

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Effects of using mobile augmented reality for simple interest computation in a financial mathematics course

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One of the most critical matters in financial mathematics consists of understanding the concept of simple interest because it establishes the basis to comprehend more complex conceptualizations. Nevertheless, students often have problems learning it. This paper aims to introduce a prototype called "simple interest computation with mobile augmented reality" (SICMAR) and evaluate its effects on students in a financial mathematic course. The methodology followed comprises three stages: i) planning, ii) development, and iii) design of information collection instruments. The stage of planning explained the problems that students confront to learn about simple interest. The stage of development discussed the logic implemented for SICMAR functionality. In the last stage, we designed two surveys to obtain the results. The pre-test survey used the attention, relevance, confidence, and satisfaction (ARCS) model to assess students' motivation in a traditional learning setting. The post-test survey was used to assess motivation, intention to use technology with the technology acceptance model (TAM), and prototype quality when students used SICMAR. Also, students answered practice exercises to assess their achievement. A total of 103 undergraduates participated in both sessions of the study. The results revealed that students expressed interest in using the prototype because of its quality and obtained higher levels of motivation and achievement than assessed in a traditional setting. Hence, SICMAR is a valuable complementary tool to learn simple interest topics.

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Abstract

One of the most critical matters in financial mathematics consists of understanding the concept of simple interest because it establishes the basis to comprehend more complex conceptualizations. Nevertheless, students often have problems learning it. This paper aims to introduce a prototype called "simple interest computation with mobile augmented reality" (SICMAR) and evaluate its effects on students in a financial mathematics course. The methodology followed comprises three stages: i) planning, ii) development, and iii) design of information collection instruments. The stage of planning explained the problems that students confront to learn about simple interest. The stage of development discussed the logic implemented for SICMAR functionality. In the last stage, we designed two surveys to obtain the results. The pre-test survey used the attention, relevance, confidence, and satisfaction (ARCS) model to assess students' motivation in a traditional learning setting. The post-test survey was used to assess motivation, intention to use technology with the technology acceptance model (TAM), and prototype quality when students used SICMAR. Also, students answered practice exercises to assess their achievement. A total of 103 undergraduates participated in both sessions of the study. The results revealed that students expressed interest in using the prototype because of its quality and obtained higher levels of motivation and achievement than assessed in a traditional setting. Hence, SICMAR is a valuable complementary tool to learn simple interest topics.

Introduction

In practically all the processes of making decisions, the economic issue appears; therefore, it is imperative knowing how money must be obtained, managed, invested, and optimized to avoid making wrong financial decisions. Financial education covers the skill and knowledge related to individuals for obtaining, managing, and investing money (Carpena & Zia, 2020).

Financial education must start at an early stage. Berry, Karlan, and Pradhan, 2018; and Sun, Yuen, Zhang, and Zhang, 2020 demonstrated how financial education helped to prevent problems such as having low credit scores or defaulting on a loan. Because of the relevance of financial education, the United States of America included various finance courses as a part of the primary school curriculum (Urban, Schmeiser, Michael, & Brown, in press). The trend was successfully adopted by other countries such as China (Ding, Lu, & Ye, 2020), Ghana (Berry, Karlan, & Pradhan, 2018), Hong Kong (Feng, 2020), and India (Carpena & Zia, 2020); however, success cannot be generalized. In Mexico, minimal interests/benefits have been reported as a consequence of implementing financial education programs (Arceo & Villagómez, 2017; Bruhn, Lara, & McKenzie, 2014).

To obtain insights about why students show no interest in financial education, we performed monitoring of undergraduates enrolled in financial mathematics courses in four northern Mexican universities. Three main problems were detected: i) students lack mathematical knowledge, ii) sometimes the techniques used by teachers to explain the basics are boring, and

iii) students did not understand the basic concepts such as simple and compound interest, which are fundamental a sound financial education.

Several alternatives have been tested to solve the difficulties faced by students to understand the basic concepts explained in a financial mathematics course. The most used options were out of class explanations, multimedia material, computer simulations, and any resource offered by the information and communications technologies (ICTs). Nevertheless, there are still opportunities to propose novel teaching-learning strategies to support students in comprehending the basics of financial education. In this paper, mobile augmented reality (MAR) technology was selected to propose an alternative learning strategy.

MAR was selected because Akcayr & Akcayr, 2017; and Arici, Yildirim, Caliklar, & Yilmaz, 2019 explained the advantages obtained when it is used in educational settings, especially in the mathematics classroom, including promote enhanced learning achievement, facilitates autonomy, positive attitudes to the educational activity, commitment, knowledge retention, interaction, collaboration, and availability for the general public.

Considering MAR advantages and the problems detected regarding financial education, this paper aims to present the development of the simple interest computation with mobile augmented reality (SICMAR) prototype and a study to assess its effects in an undergraduate financial mathematics course. The study, divided into pre and post-test, was designed to assess students' motivation, achievement, technology acceptance, and prototype quality. Accordingly, this paper poses the following 12 hypotheses:

- Regarding students' motivation

H₁: There is a significant difference with regards to attention scores achieved by students in the pre-test and the post-test.

H₂: There is a significant difference with regards to relevance scores achieved by students in the pre-test and the post-test.

H₃: There is a significant difference with regards to confidence scores achieved by students in the pre-test and the post-test.

H₄: There is a significant difference with regards to satisfaction scores achieved by students in the pre-test and the post-test.

H₅: There is a significant difference with regards to motivation scores achieved by students in the pre-test and the post-test.

- Regarding students' achievement

H₆: Students solve simple interest problems more often correct when SICMAR is employed.

- Regarding technology acceptance

H₇: Quality positively affects students' perceived usefulness of SICMAR.

H₈: Quality positively affects students' perceived ease of use of SICMAR.

H₉: Perceived ease of use positively affects students' perceived usefulness of SICMAR.

H₁₀: Perceived ease of use positively affects students' intention to use SICMAR.

H₁₁: Perceived usefulness positively affects students' intention to use SICMAR.

- Regarding SICMAR quality

H₁₂: The mean quality value of SICMAR evaluated by students is greater than 3.8.

The main contributions of the paper are summarized below.

1. We introduce the basis to create the SICMAR prototype.
2. We offer a proposal to assess students' motivation, achievement, technology acceptance, and SICMAR quality in a real educational setting.
3. We explain the facts to support that SICMAR could be a valuable complementary tool to learn simple interest.

The rest of the paper is organized as follows: Section 2 discusses related work about AR to support mathematical learning. In Section 3, the basis to build SICMAR and the surveys created are described. The results obtained from tests and the corresponding discussion are shown in Section 4. Finally, Section 5 presents the conclusions derived from this research work and proposes future directions.

Learning Mathematics with Augmented Reality

A considerable amount of research studies has focused on MAR usage for educational purposes. For this study, we searched for papers related to the use of augmented reality for mathematics teaching-learning. The period considered for the investigation ranged from 2013 to mid-2020. The terms searched were "mathematics," "financial mathematics," "augmented reality," "mobile augmented reality," "teaching," "education," and "learning." Moreover, we used the Boolean operators "OR," "AND," to mix multiple search terms. We searched to collect papers from journals included in the journal citation reports (JCR) and manuscripts published in conferences through the Web of Science (WoS). Consequently, 15 papers were discovered and analyzed. A summary of the features detected is shown in Table 1.

Surprisingly, as shown in Table 1, only a few works focused on learning mathematics, and there are no signs of papers related to financial mathematics, either for the computation of simple interest. Regarding the preferred software for implementation, Vuforia was the leading. The number of participants varies from 2 to 140; it is clear there is no consensus about the sample size to validate a study. Concerning the level, undergraduate and elementary were the most repeated scenarios. Tobar, Fabregat, & Baldiris, 2015; and Cascales, Martínez, Pérez, & Contero, 2017, exemplified the advantages of using MAR to learn mathematics in special education needs (SEN) contexts. Only three works presented assessments about students' motivation. Most of the work concentrated on prototype perception and students' achievement. No work focused on assessing technology acceptance, while the authors qualitative argues was the most common theory base employed, followed by the Wilcoxon test. Most of the technologies used to

implement the prototypes were mobile devices, which evidences that PCs were less preferred and that lenses were not yet daily used in academic scenarios, mainly due to the high cost. Moreover, all the work analyzed introduced single-user based applications; this is because it is still complex to build collaborative applications, which undoubtedly will enhance the student's experiences. Based on the analysis conducted, our proposal is the first attempt that addressed simple interest computation and assessed students' motivation, achievement, quality, and technology acceptance in the same study.

Materials & Methods

In this research, we used a mixed-method to allow the complete and synergistic usage of qualitative and quantitative data (Reeping, Taylor, Knight, & Edwards, 2019). Also, this research was considered exploratory-descriptive. Exploratory, because in an early stage, we understood the problem in-depth and gained insights to know what is happening, and descriptive, because we obtained information about the current phenomena state. The methodology followed comprises three stages: i) planning, ii) development, and iii) design of information collection instruments.

Planning

After maintaining a dialogue with three financial mathematics professors, the planning stage began. We explained the problems detected in the monitoring realized, and professors agreed with us. However, professors mentioned additional students' barriers when learning simple interest: a) problem statement is not understood, b) confuse simple interest with compound interest and vice versa, c) the terms involved are incorrectly cleared, d) the concepts associated such as principal, interest rate, and time are misinterpreted, and e) conversions between time units are wrongly performed. Surprisingly, professors determined that around 70% of students commit at least one of the mentioned errors. They also stated that simple interest knowledge is fundamental to understand complex concepts such as compound interest, amortization tables, and annuities. Hence, the topic must be well understood by students.

We realized a study to understand how simple interest is computed and to identify the main terms involved. As a result, the following five terms were identified.

- **Principal (P).** Also called present value, it is the original sum of money borrowed and can be computed as:

$$P = \frac{A}{1 + rt}, \quad (1)$$

where A is the amount, r is the interest rate, and t is the time (number of periods).

- **Amount (A).** The total accrued amount (principal + interest) represents the future value of the financial operation, and it is calculated by equation 2.

$$A = P(1 + rt). \quad (2)$$

- **Time (t).** Represents the period of the financial operation; it is defined as:

$$t = \left(\frac{1}{r}\right)\left(\frac{A}{P} - 1\right). \quad (3)$$

- **Interest rate (r).** It is the amount charged on top of the principal for the use of assets. It is expressed as a percentage of the principal and computed with equation 4.

$$r = \left(\frac{1}{t}\right)\left(\frac{A}{P} - 1\right). \quad (4)$$

- **Simple interest (I).** Represents the price of the money along the time. It is the fee to pay on a loan or income that earn on deposits, and it is computed with equations 5 or 6.

$$I = Prt, \quad (5)$$

$$I = A - P. \quad (6)$$

In equations 1 to 6, r is frequently applied for one year. However, it could also be expressed in days, weeks, fortnight, months, bimonthly, quarters, four-monthly, or semester. If in the calculation, the period for r and t is defined in different units, then the corresponding conversions must be computed, which often causes mistakes.

After understanding how simple interest is computed, we gained interest in designing a prototype to support students in learning this topic. Hence, we defined five characteristics the prototype must comply with to overcome the barriers expressed by professors. i) A set of markers will be used to determine the term to compute and the parameters involved, ii) 2D models will represent all the information needed for the calculation, iii) Markers' movement will allow observing the 2D models from different perspectives, iv) The calculation to be solved will be defined with a combination of markers (interaction), and v) Virtual objects, such as text boxes, arrows, and images will be employed to step-by-step explain calculations.

From the great variety of information and communication technologies (ICTs), personal computers (PCs) and mobile devices were contemplated to implement the prototype due to the high probability that a student has either one. Nevertheless, recent studies have shown that almost 75% of AR works for educational settings were implemented on mobile devices obtaining satisfactory results. Young users prefer mobile devices because it can be used anytime, carried from place to place, and connected to the Internet all day long. Therefore, mobile devices were selected to implement the solution.

From the variety of market options, Android and iOS-based mobile devices are the leaders. Nevertheless, Android was chosen to implement the prototype due to: a) it is the leading mobile operating system worldwide, b) the price for publishing an app in the play store is much lesser than posting an app in the apple store, c) the cost of Android-based devices is less than iOS-based devices; due to price, a student rarely has an iPhone, d) possesses a good support architecture and functional performance, e) the customization level offered makes it easy to use, and f) due to the variety of battery sizes easily overpower the iPhone (Ivanov, Reznik, & Succi, 2018).

Ultimately, we decided to develop a prototype called "simple interest computation with mobile augmented reality (SICMAR) " and to design two surveys to assess the effects of use it on the students learning process.

Development

In the market, there are various alternatives to implement AR solutions, including Wikitude, ARToolKit, Augmenta, Easy AR, HP Reveal, and Vuforia, among others, each one offering exciting characteristics. By considering the analysis presented in Table 1 and based on the authors' experience, Vuforia Software Developer Kit (SDK) was selected. Vuforia is a robust platform that contains the libraries to implement the tasks related to AR, including the real-time marker detection, recognition and tracking, and the computations for object superimposition. Furthermore, Unity 3D was employed to create the SICMAR visual environment and all the 2D virtual objects that will be superimposed on each marker.

SICMAR was designed based on the framework proposed by Barraza, Cruz, & Vergara (2015), shown in Fig. 1.

Unity 3D was used to build the rendering, also called the presentation subsystem. Two main tasks were executed: 1) displaying the video acquired from the real world, and 2) the rendering of the 2D models. We designed a touch-based graphical user interface (GUI) to display the components and the video acquired from the mobile device. At the top of the GUI, two sections were inserted: a) input data, and b) calculate (output). The first show the input terms (markers) detected inside the scene, and the second shows the corresponding letter of the term the user wants to compute (see Fig. 2). Also, Unity sprite renderer was employed for rendering all the photorealistic images of the 2D models that will be superimposed inside the real-world video stream.

The context and world model subsystems include creating the image targets (markers), the data about the interest points, and the 2D objects that are going to be used in the augmentation. We used the Brosvision marker generator to design the set of markers to represent each of the five terms explained in Equations 1-6. As shown in Fig. 3, the markers include lines, triangles, and quadrilaterals, and at the center, a square with a letter corresponding to the simple interest term was added. Using Vuforia, we conducted a test of the contrast-based features (interest points) of the individual markers visible to the camera. All the markers earned five stars rating, which means they included excellent features for detection and tracking.

Then, four different kinds of 2D objects were created for user interactions/augmentations, as shown in Fig. 4.

- (a) Objects to display information about the detected marker (input term).
- (b) Objects to represent the user data inputs and to determine if a term will be handled as input or output.
- (c) Objects to display information about the time conversions.
- (d) Objects to display the result of the calculation (output term), or to show an error.

Vuforia SDK was employed to carry out the tracking subsystem. The subsystem exchanges marker tracking information with the rendering subsystem to superimpose the virtual 2D objects to the original scene displayed to the user.

The interaction subsystem collects and processes any input required by the user. A series of C# scripts were linked to GUI objects. Therefore, when a tap occurs on the screen, verification is made to determine if an element was touched. If the verification is valid, the search for a marker starts. If a marker is detected inside the scene, then the corresponding method is invoked to carry out the task.

The logic implemented to solve any of the equations 1-6 is: when SICMAR is executed, the presentation screen is displayed and the camera of the mobile device begins to capture scenes. When the user shows a valid marker in the front of the camera, it is recognized as the desired output, then, its position, rotation, and perspective are computed, and the corresponding virtual object is superimposed accordingly to the view of the real scene. Next, the input checkbox is activated, and the prototype waits for the user to show the markers for input terms. When input markers are recognized, the text boxes to insert data are presented, and the corresponding 2D objects are superimposed inside the real scene. Any marker different from the first selected can be used as input. The user must insert the data corresponding to each term with the keyboard of the device. Once the data was introduced, the input checkbox must be disabled to perform the computation. Immediately, a verification is performed to detect if the necessary data for the computation were inserted correctly. If there is any missing data, an error object is displayed, else the output calculated is presented. The process can be executed continuously.

An example of simple interest computation is shown in Fig. 5. If the prototype detects that r and t were inserted at different periods, then the associated conversions are computed. As shown in Fig. 6, the user selected quarters for r and fortnights for t , and at the bottom, the value obtained from the conversion is displayed and explained.

Design of Information Collection Instruments

We designed two surveys to assess SICMAR. The first served to obtain information about students' motivation when the professor explained the simple interest topic with traditional materials (textbooks, slides, and whiteboards). The second survey included items to gather data about students' motivation with SICMAR, technology acceptance, and prototype quality.

The first survey comprises two sections. The first included items to collect students' general information, such as name, gender, and age. The second contained items related to Keller's Attention, Relevance, Confidence, and Satisfaction (ARCS) motivation model (Li & Keller, 2018). ARCS was used in the literature to observe if MAR could be a resource that motivates students to learn a subject, obtaining promising results (Cabero-Almenara & Roig-Vila, 2019; Estapa & Nadolny, 2015; Ibáñez, Uriarte, Zatarain, & Barrón, 2020). Motivation is a fundamental activity that must be performed to attract and sustain students' attention (A), to define why students need to learn a content (R), to help students to believe they succeed making efforts (C), and to assist students in obtaining a sense of reward (S) (Li & Keller, 2018).

IMMS is a traditional instrument used to assess students' motivation based on the ARCS model, which includes 36 items: 12 for (A), 9 for (R), 9 for (C), and 6 for (S). Although IMMS was extensively used, it is known that it is long, and not all items were necessary, especially those measured in a negative or reverse way. Therefore, the reduced IMSS (RIMMS) proposed by Loorbach, Peters, Karreman, & Steehouder (2015) was employed. RIMMS comprises 12 Likert five-point scale items, three for each ARCS dimension, and the original version was adapted to the lesson of simple interest as can be consulted on the left side of Table 2.

The second survey comprises four sections. The first includes items to collect students' general information, and the second includes the 12 RIMMS items adapted to assess students' motivation with SICMAR (see the right side of Table 2).

The third section, shown in Table 3, aimed to assess students' intention to use SICMAR employing the extended technology acceptance model (TAM) proposed by Davis. TAM indicated that perceived ease of use (PEOU) and perceived usefulness (PU) were the two central beliefs that determined people intend to use a technology (ITU). PEOU refers to the degree to which a person believes that using a system would be free from effort. PU refers to the degree to which the user believes that a system would improve his/her work performance. Finally, ITU is used to measure the degree of technology acceptance (Hamidi & Chavoshi, 2018). TAM section comprises four items for PU, five for PEOU, and two for ITU. The 11 items based on the Likert five-point scale were adapted from the work of Miranda, Vergara, Cruz, García, & Favela (2016).

The fourth section was created to gather information about SICMAR quality. The ten items based on the Likert five-point scale were adapted from the proposal by Barraza *et al.* (2015). The items advocate collecting information about SICMAR design, content, and interaction that together determined quality, as can be observed at the bottom of Table 3.

Finally, Universidad Autonoma de Ciudad Juarez by means of the Institute of Engineering and Technology, emitted the approval to use the data and reviewed the consent form that will be filled out by the students.

Results

The study was conducted at the beginning of March 2020. A classroom at a public university located in northern Mexico was used as an educational setting. One of the professors that participated in the planning stage organized the two sessions that comprised the study. Both sessions were conducted with three days of difference.

Before the experiment, students did not have prior knowledge of the concepts related to simple interest. Students were informed about the goal of the research and that the data obtained will be treated with absolute confidentiality and used only for academic purposes. Also, students were informed that they were not forced to participate. Moreover, students completed a consent form regarding data use. The non-probabilistic sampling technique was employed for convenience, and due to restrictions imposed by the university, the sample was not divided into a

control and experimental group. In summary, 139 students enrolled in the financial mathematics course were surveyed.

In the first session, which lasted two hours, the professor explained the simple interest theme by employing traditional materials. Then, students were asked to realize a practice consisting of five exercises (see two examples in the first column of Table 4) and fill out the first survey. At the end of the first session, students were requested to get an Android-based mobile device for the second session.

The second session lasted one and a half hours and started with an explanation about the use of SICMAR. Afterward, each student received a set of markers. Fortunately, all students brought the Android mobile device. Hence, a great variety of smartphones with different features were used, which was important to observe that SICMAR can be executed in various devices. The mean time to interact with the prototype was 39 minutes. Next, students were asked to realize a practice consisting of five exercises different from those used in the first session, but with similar difficulty (see two examples in the second column of Table 4), and to fill out the second survey. In both sessions, students answered the surveys through the Internet (Microsoft forms) and practical exercises on a sheet of paper. The idea was not only to review the answer, but also the procedure followed to obtain the result. An example of students testing SICMAR is shown in Fig. 7.

Preliminary Data Analysis

Data collected from surveys was downloaded to create a database employing IBM SPSS software. The responses obtained were minutely revised, 36 missing values were identified, and no outliers were distinguished. Therefore, the final sample comprises data from 103 students.

The final sample size was deemed appropriate due to: 1) $M=58.76$ was obtained by calculating the data mean of the fourth column in Table 1; therefore, our sample almost doubled that value. 2) The section related to ARCS is the biggest of our Surveys; therefore, the rule of thumb that a sample should have at least five times as many observations as there are variables to be analyzed was fulfilled ($5 \times 12 = 60$).

From the general data section, $n=59$ (57.28%) were female, and $n=44$ (42.72%) were male. Age ranges from 18 to 30 years ($M=19.74$, $SD=1.93$). The internal reliability of the surveys was measured with Cronbach's Alpha (α); the values obtained are summarized in Table 5. The total item correlation computed does not reflect the necessity of dispense with any item. Almost all the values were considered good-excellent, except R in pre-test ARCS that was considered acceptable.

Students Motivation Assessment with ARCS

This part of the study allowed us to observe if an increase in motivation was obtained when comparing the professor's lesson and SICMAR. The mean and standard deviation calculated for each item are displayed in Table 2. All scores exceed the central value of the scale. Moreover, greater mean value was always obtained with SICMAR. The minimum difference was observed for (A) ($4.14-3.95=0.19$), and the maximum for (R) ($4.38-3.87=0.51$). A total difference of ($4.17-$

3.87=0.3) was obtained, which begins to show insights of motivation increase. By observing SICMAR results, students expressed high levels for (A), (R), (C), and (S), which demonstrated an increase from pre-test to post-test.

Nevertheless, it was necessary to determine when the differences obtained were statistically significant. First, it was known that data coming from RIMMS were normally distributed; therefore, the paired t-test with a 5% level of significance was calculated, obtaining: $t=-1.761$ for (A); $t=-6.120$ for (R), $t=-2.281$ for (C), $t=-2.877$ for (S), and $t=-3.613$ for the entire ARCS. The p-value less than or equal to 0.05 was considered significant, and the value greater than 0.05 was non-significant. Considering that the null hypothesis was that there is no significant difference between pre-test and post-test scores:

- **H₁**: Is *rejected*. $p=0.081$ was obtained; therefore, the difference of 0.19 was not significant regarding (A).
- **H₂**: Is *accepted*. There is sufficient statistical evidence ($p=0.000$) to support that with SICMAR, a mean increase of 0.51 on students' (R) was obtained.
- **H₃**: Is *accepted*. The difference of 0.21 (4.08-3.87) was significant regarding the (C) dimension with $p=0.025$.
- **H₄**: Is *accepted*. $p=0.005$ was obtained; hence, there is a significant difference of 0.3 about students' regarding (S).

Also, path analysis was performed to compute total effects among ARCS four dimensions and to determine students' motivation. The results are depicted in Fig. 8. The standardized factor loadings above the arrows correspond to the pre-test, and below the arrows correspond to the post-test. Also, the determination coefficient (R^2) was calculated to measure how close the data were to the fitted regression line. The R^2 values for the pre-test are shown in the upper right corner and the lower right corner for the post-test.

It is noted from Fig. 8 that a significant direct effect exists from A->R, from R->C, and C->S with a significance level of 5% for both tests. Hence, the hypothesis:

- **H₅**: Is *accepted*. Students increased their motivation whit SICMAR usage. The value $M=4.17$ is greater than $M=3.87$ obtained with the professor's materials. The difference of 0.3 is statistically significant with $p=0.000$. The difference represented an increase of 7.75%. Moreover, the mean values were greater for all ARCS dimensions with SICMAR, so the sum of all means and the path analysis corroborated the motivation increase.

Assessment of Students Achievement in Practice

The professor qualified each item of the practice exercises. An item obtained a dichotomous value of correct or incorrect; therefore, the final grades go from 0 to 100 (20 points for each correct answer). An item is correct only if the result and the procedure to obtain the response

were good. Some students presented good results, but with a wrong procedure, these cases were qualified as incorrect.

For the pre-test, the values $M=39.02$ and $SD=28.88$, and for the post-test, $M=66.60$ and $SD=29.02$ were obtained. An increase of 70.68% on post-test grades was observed. For the post-test, 25 students obtained the maximum grade (100), and only four students received that grade in the pre-test. Fourteen students obtained better grades on the pre-test than post-test. In both sessions, women obtained better grades, with pre-test values of $M=44.06$, $SD=27.41$, and the post-test of $M=76.61$, $SD=20.41$. The pre-test values obtained for men were $M=32.27$, $SD=30.56$, and for the post-test, were $M=53.18$, $SD=31.38$.

The test of Kolmogorov-Smirnov was employed to select the statistical analysis tool accordingly to the data distribution. The results obtained with a 5% level of significance using SPSS for the pre-test were $Z=0.162$, $p=0.000$, skewness=0.285, skewness standard error=0.238, kurtosis=-0.885, and kurtosis standard error= 0.472; for the post-test were $Z=0.192$, $p=0.000$, skewness=-0.675, skewness standard error=0.238, kurtosis=-0.396, and kurtosis standard error=0.472; and for the differences (pre-test-post-test) were $Z=0.109$, $p=0.004$, skewness=-0.329, skewness standard error=0.238, kurtosis=0.242, and kurtosis standard error=0.472. Hence, the normality hypothesis was rejected; then, the two paired Wilcoxon signed-rank test was utilized to observe the significance of grade differences. The values obtained were $Z=-6.129$, $p=0.000$, and medium effect size $d=-0.427$. Therefore:

- **H₆:** Is *accepted*. Indeed, students hit on average 3.33 times with SICMAR, and 1.95 with professor's material, obtaining a difference of 1.38, which is statistically significant.

SICMAR Technology Acceptance Assessment

Our study extended TAM by including the quality external variable and used it to know if students are willing to use SICMAR. The structural equation modeling (SEM) approach was selected to conduct data analysis (Al-Gahtani, 2016). AMOS software was used to examine the effects between observed and latent variables and the validity of the proposed hypotheses. The aim was to observe if quality, PEU, and PU were factors that affected students' intention to use (ITU) SICMAR.

First, the variables and the relationships between them were established. The model in Fig. 9 comprises four latent variables (represented with spheres) and 21 observed variables (represented with squares). The relationships were symbolized with unidirectional arrows. From the four latent variables, the quality was independent because no arrow was connected to it, and the remainder were dependent (at least one arrow was connected). A direct effect is a relationship that exists between one variable to another. An indirect effect is a relation between two variables mediated by at least one or more different variables. The sum of direct and indirect effects determines the total effect.

The second stage determined if there was enough information to test the model. SEM identification was verified by computing the model degrees of freedom (DoF). It was expected to

obtain a value greater than 0 (over-identified), which means more information than parameters to estimate. $DoF=184$ was obtained; therefore, model over-identification was established.

Afterward, the values specified by the sample variances and covariances were calculated. The aim was to obtain the values that provide a reproduced matrix that best fit the observed matrix. A model fits the data well if differences between observed and predicted values are small. For this purpose, the maximum likelihood was employed.

A summary of the values obtained is shown in Table 6. It was expected that: χ^2/DoF ranged 2-3, a GFI value near 1, RMR closer to 0, all three were fulfilled, just to mention a few examples. With the complete analysis, the good-fitting measurement was determined.

R^2 values were computed to measure the proportion of variance of the dependent variables explained by the independent variables. The three values obtained were good, as is shown in Fig. 9.

The standardized factor loadings (path coefficients) and its p-values were computed to determine the acceptance or rejection of the five hypotheses (see Table 7). The 21 observed variables relations to latent variables were accepted with a confidence value of 1%, as can be observed in the last column of Table 3. It is worth highlighting that for quality, the variables Q9 and Q10 related to markers were the most important. For PEU, the greater values were obtained for PEU2 and PEU4, which address the familiarity using technology and control manipulation. Regarding PU, it is noted that PU3 and PU4 were the most important, which refers to SICMAR usability to learn and remember concepts. The highest value was obtained for ITU1, where students expressed their interest in keeping using SICMAR.

Finally, the direct, indirect, and total effects among the five hypotheses were analyzed, and the results can be observed in Table 8.

In summary, for the five TAM hypotheses:

- **H₇**: Is *accepted*. Effectively, quality has a significant direct effect on PU and establishes an essential indirect effect on ITU when it passes by PU.
- **H₈**: Is *accepted*. There exists a significant direct effect from Quality->PEU and a weak indirect effect on PU when it passes by PEU.
- **H₉**: Is *rejected*. A direct effect was found from PEU->PU; however, the relationship was not statistically significant.
- **H₁₀**: Is *rejected*. The weakest and non-significant path obtained from the whole SEM corresponded to PEU->ITU. PEU was not considered by students to assess PU and neither for ITU.
- **H₁₁**: Is *accepted*. A direct effect was obtained from PU->ITU. Students considered that PU was essential to support their ITU SICMAR frequently.

Based on the results, it can be concluded that students expressed their ITU SICMAR due to the quality and the total effect of 0.738 encountered in Quality->PU->ITU that was considered good.

SICMAR Quality Assessment

SICMAR quality was demonstrated with SEM results. However, an additional analysis was conducted. As shown in Table 3, the total scores obtained ($M=3.93$ and $SD=0.62$) demonstrated that most students considered SICMAR a good quality prototype. The minimum value obtained ($M=3.16$) was regarding item Q5, suggesting enlarging the buttons for better manipulation. The next minimum corresponds to Q10 ($M=3.56$), reflecting that sometimes students could not easily manipulate the device and the markers simultaneously. The better results correspond to Q1 ($M=4.45$) and Q6 ($M=4.40$), which demonstrated that all the simple interest terms were included, and the velocity of response was fast.

Data obtained from quality were normally distributed; therefore, one-sample t-test with a significance of 1% and a reference value of 3.8 was performed, obtaining $t=2.126$, $p=0.036$, and $d=0.20$; therefore:

- **H₁₂**: Is *accepted*. A significant difference was obtained when comparing $M=3.93$ with the reference value (3.8). As was mentioned in the TAM study, SICMAR has much quality that influences the students' ITU.

No MAR works that expressed a hypothesized mean value of quality that served for comparison were found. Therefore, the minimum and the maximum length of the Likert scale were determined. First, the range was calculated by subtracting ($5-1=4$); then, the result was divided by five ($4/5=0.80$). Afterward, the range was added to the least scale value to obtain the maximum. Hence, ranges computed were 1--1.8--2.6--3.4--4.2--5. For instance, amounts greater than 3.4 and less or equal than 4.2 were considered as much quality. Thus, the average value of 3.8 was supposed to determine much quality, which was also the median obtained.

Discussion

With the results obtained, we effectively observed that MAR could potentially be applied to any study area obtaining the benefit of improving the user perception and interaction with the real world; a non-AR application cannot offer that feature.

Our motivation results were consistent with those reported in the analyzed papers in Table 1. MAR changes how students interact with the world, and as a result, students' motivation to learn increases. According to the professor, students became more engaged during the post-test session, and this is mainly due to the different and interactive ways for presenting the information. Also, MAR could turn a classic learning process into an engaging experience (students perceived learning as a game). The critical elements for students' motivation were the interactive representations of time conversions, the 2D models, and how markers interaction determined the calculation to be computed. The fact of using ICTs also influences. Moreover, the younger participants felt more comfortable and engaged with SICMAR, as was expected.

According to Loorbach *et al.* (2015), (C) influences students' persistence and accomplishment. Hence, it is crucial for motivation. In our post-test study, $C=4.08$ positively affects students'

motivation. The main differences detected when comparing our findings with the works by Estapa, & Nadolny (2015), Cascales *et al.* (2017), and Ibáñez *et al.* (2020) were that our sample size is the biggest, we used RIMMS instead of IMMS, which causes students were less worn, and that we utilized path analysis to demonstrate that ARCS scores showed the significant motivation increase of 7.75%.

With SICMAR, students achieved significantly better when answering practice exercises, obtaining an increase of 70.76%. The works by Estapa & Nadolny (2015), Tobar *et al.* (2015), and Ibáñez *et al.* (2020) reported about students' achievements; however, they measured the time used to execute the tasks, unlike our proposal that qualified the answers of practice exercises. Purmana *et al.* (2014) reported an increase of 17% in the learning process; however, how it was measured was never explained. Coimbra *et al.* (2015) presented only qualitative preliminary explanations about math learning enhancing, so comparisons cannot be provided.

None of the works in Table 1 addressed TAM; hence, no comparisons can be offered. However, it must be noted that the path Quality->PU->ITU was the most significant. Students considered the concepts explained, calculation speed, the results offered, and the size and color of texts displayed as the most critical issues to determine quality. Students considered SICMAR useful for learning, and it helped to remember the concepts related to simple interest easily. Finally, students determined SICMAR quality as good enough to use the prototype frequently.

Conclusions

In this paper, the methodology to develop the SICMAR prototype was presented. The app was conceived to help students with the learning of the simple interest topic. To the best of our knowledge, SICMAR was the first effort to design a MAR application devoted to simple interest learning in financial mathematics. The concepts addressed, including principal, amount, time, interest rate, and simple interest, were considered fundamental to promote students' financial education. SICMAR was tested in a real university setting to assess its quality, students' motivation using ARCS, the achievement by answering practice exercises, and technology acceptance with extended TAM. The results obtained from tests with 103 participants revealed that undergraduate students were interested in to frequently use SICMAR because of its quality, were motivated to learn simple interest topics, and increased their achievement in answering practice exercises. All this conveys to conclude that SICMAR is a valuable complementary tool to learn issues related to simple interest computation.

After experimentation, several limitations were noted. Some students focused attention on the application and not on the essential parts of the topic to learn. This fact has been earlier studied as an attention tunneling effect, and this can be the explanation of why some students scored lower using SICMAR. Also, not all students felt comfortable using SICMAR, which offered clues that some persons could be challenging using ICTs. Moreover, the issues related to gender were not in-depth-analyzed, which is currently a trend in the AR field.

Extensions of the proposed study may include the possibility of enhancing the interaction environment, increase the sample, measure the cognitive load, involve more teachers of financial

mathematics to the study, and design other themes about financial mathematics. Finally, it would be recommendable to run a pilot study with Microsoft Hololenses to observe if the possibility of not using the hands increases the motivation and achievement of students.

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Figure 1

The framework followed to design SICMAR.

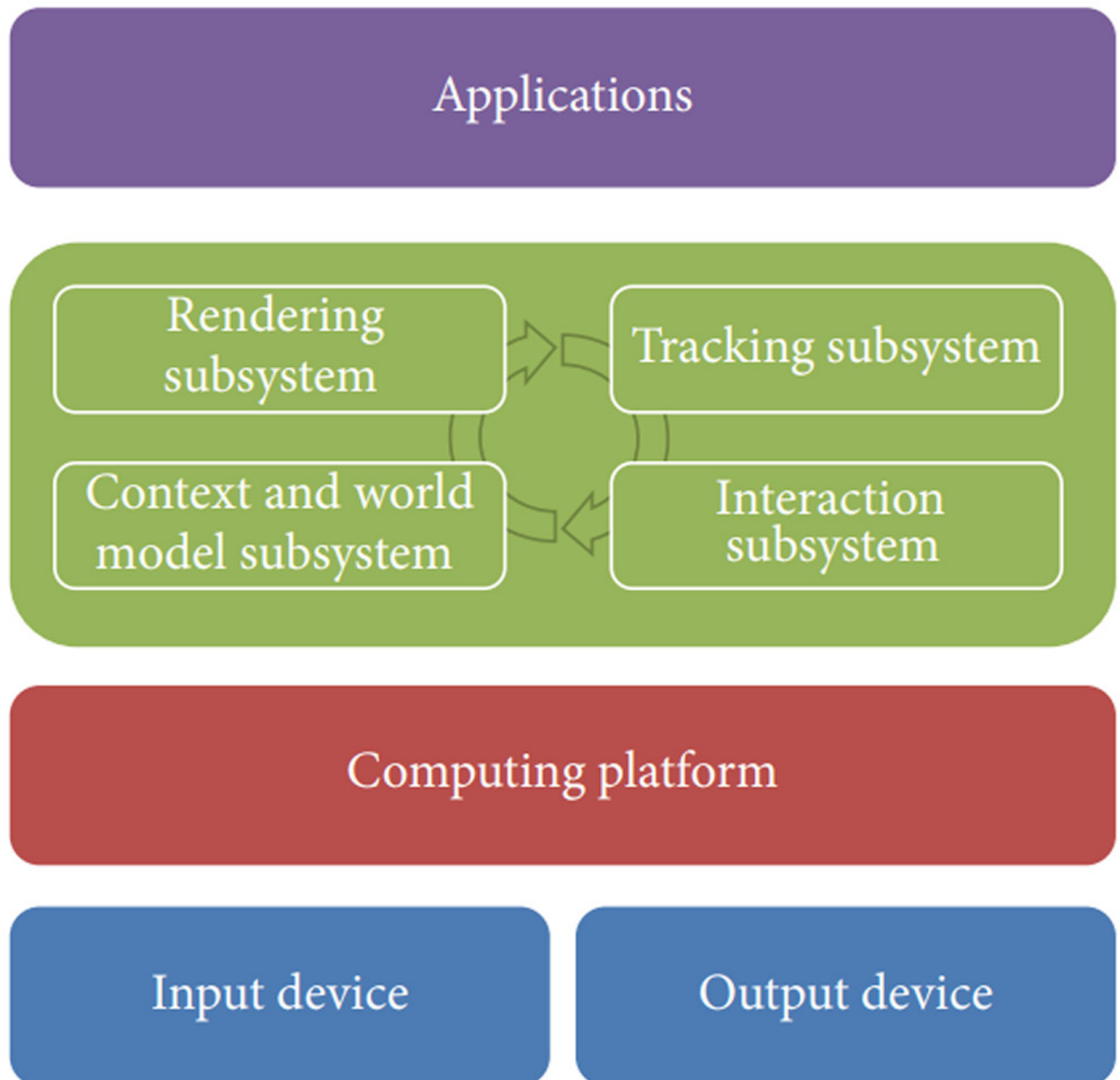


Figure 2

SICMAR top screen sections.

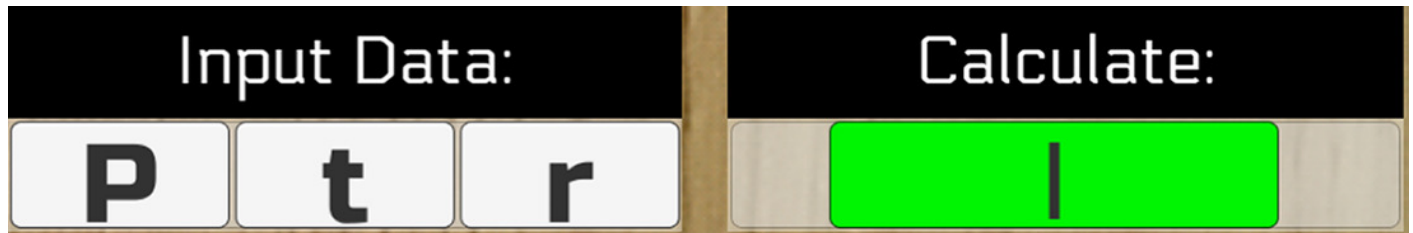


Figure 3

The set of five SICMAR markers: (a) Principal, (b) Amount, (c) Time, (d) Interest rate, and (e) Simple interest.

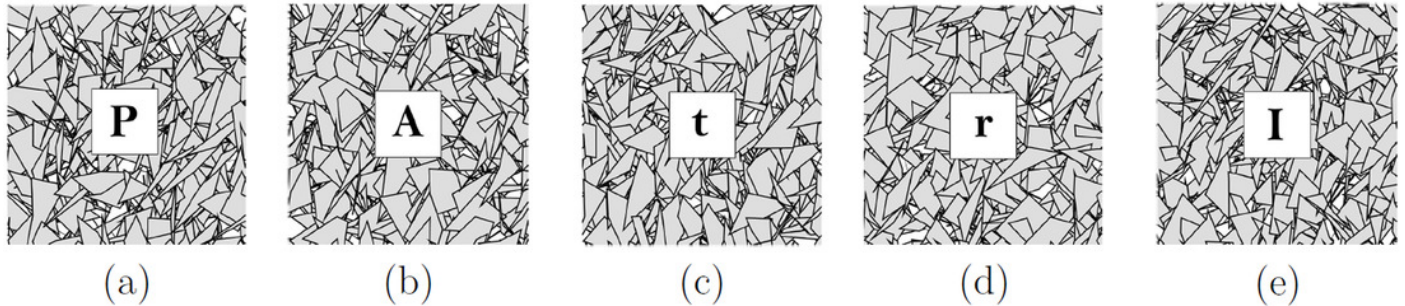


Figure 4

SICMAR 2D objects: (a) Objects to display information, (b) Interaction controls, (c) Objects to show conversions, and (d) Objects to show a result.

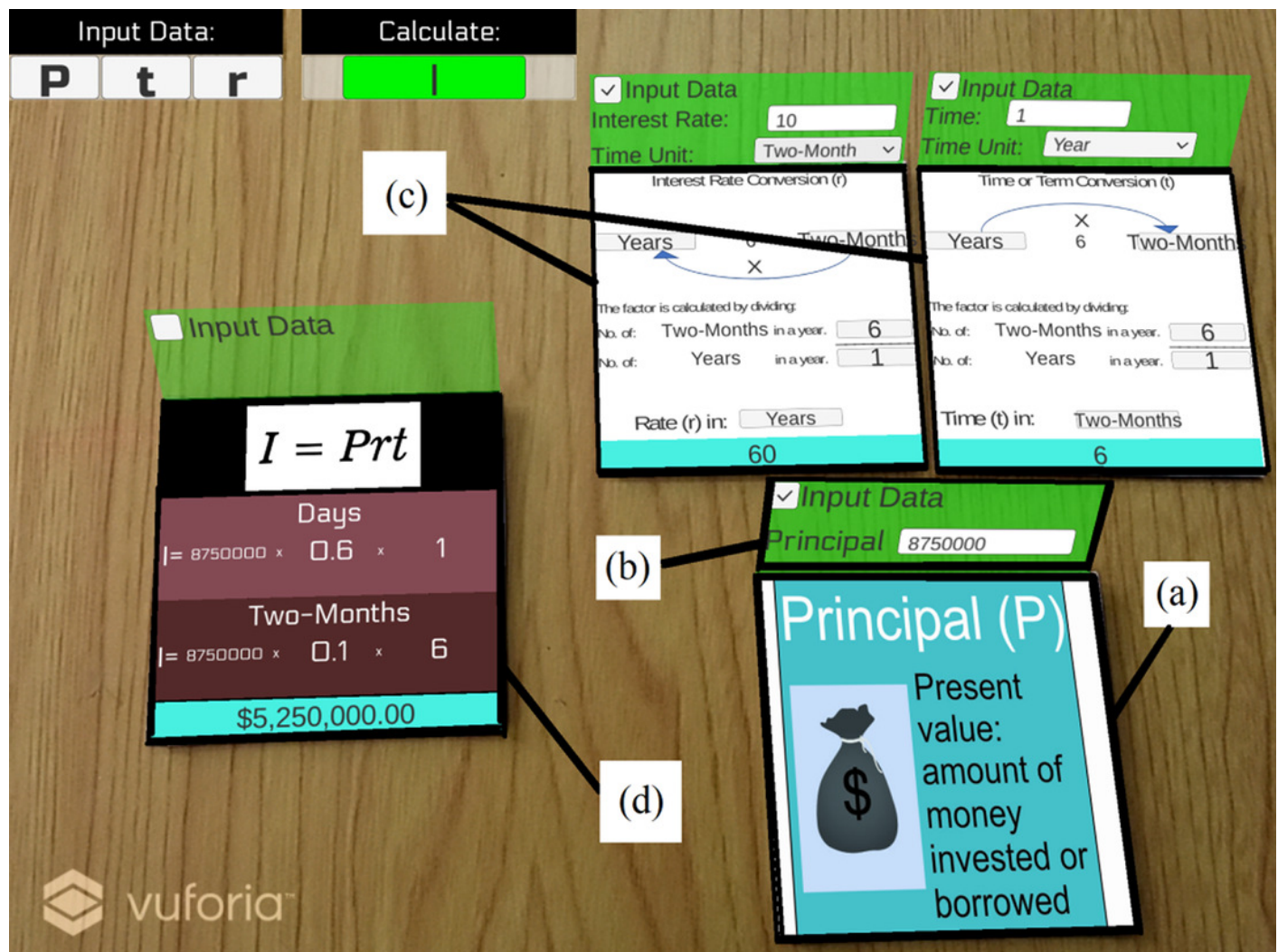


Figure 5

The screen for simple interest computation.

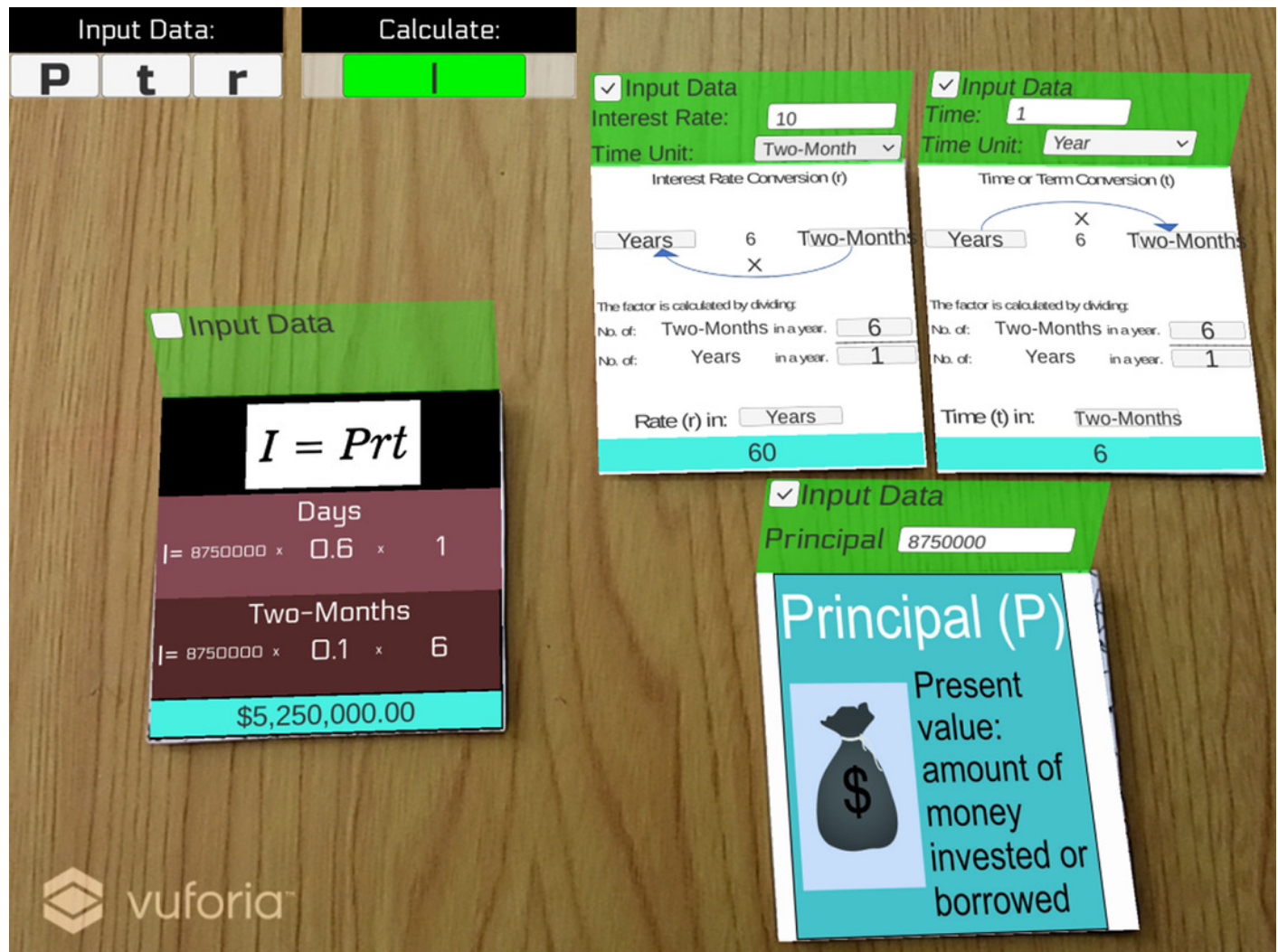


Figure 6

An example of the conversion of r and t terms.

Input Data:

Calculate:

t

r

☒ Input Data

Time:

Time Unit:

Time or Term Conversion (t)

Quarters

6

Fortnights

$\div$

The factor is calculated by dividing:

No. of:	Fortnights	in a year.	24
No. of:	Quarters	in a year.	4

Time (t) in:

0.3333333333

☒ Input Data

Interest Rate:

Time Unit:

Interest Rate Conversion (r)

Quarters

6

Fortnights

$\div$

The factor is calculated by dividing:

No. of:	Fortnights	in a year.	24
No. of:	Quarters	in a year.	4

Rate (r) in:

1.3333333333

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Figure 7

An example of students testing SICMAR application.



Figure 8

Standardized path coefficients of the ARCS models.

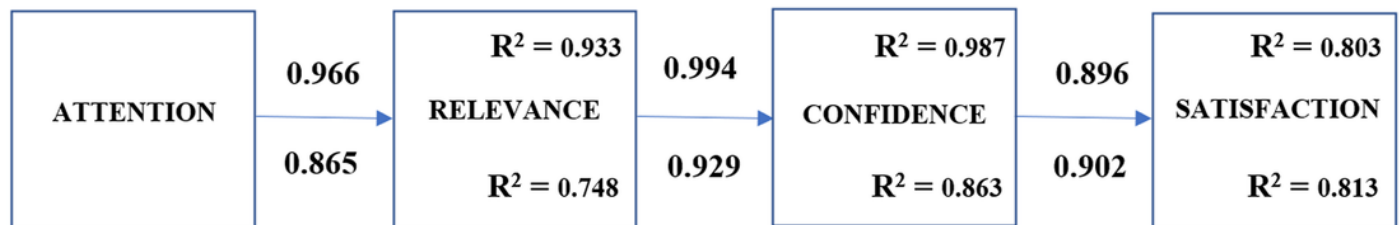


Figure 9

The structural equation model proposed and its standardized factor loadings.

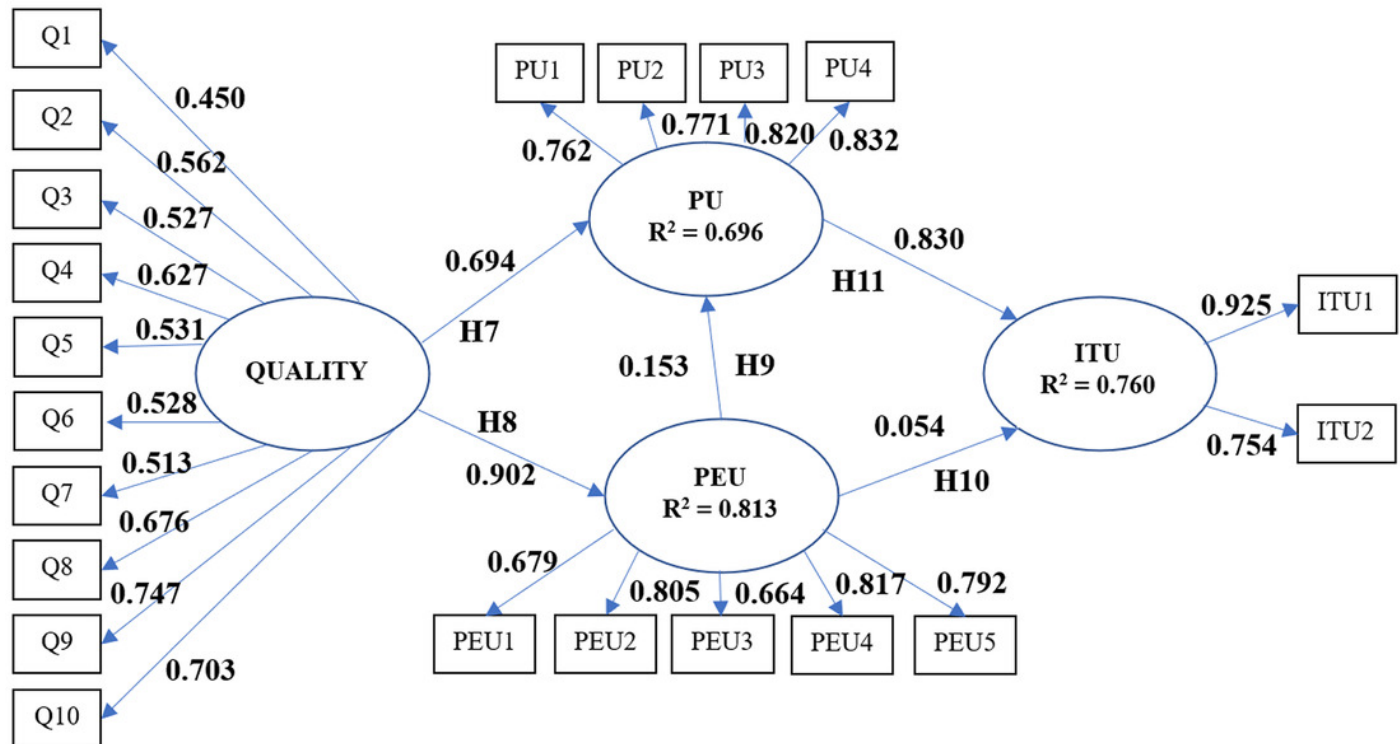


Table 1 (on next page)

A summary of 15 experimental augmented reality studies focused on learning mathematics.

1

Table 1. A summary of 15 experimental augmented reality studies focused on learning mathematics.

Author(s)	Software	APP Name	Sample	Subject to learn	Learners	Assessment	Theory base
Salinas <i>et al.</i> (2013)	N/A	TEAM	30	Algebraic functions	Undergraduate	Prototype perception	Authors qualitative argues
Sommerauer and Muller (2014)	Aurasma studio	Mathematics exhibition	101	Mathematics	Mathematics exhibition visitors	Knowledge retention	Wilcoxon test
Purnama <i>et al.</i> (2014)	Open CV	ARGLT	N/A	Geometry	Elementary	Achievement	Percentages
Estapa and Nadolny (2015)	Layar creator	Mathematics instruction	61	Dimensional analysis	High school	Achievement and Motivation	F-test, and ARCS
Barraza <i>et al.</i> (2015)	Vuforia SDK	pARabola	59	Quadratic equations	Undergraduate	Prototype perception	Authors qualitative argues
Tobar <i>et al.</i> (2015)	Nyartoolkit	Gremlings in my mirror	20	Mathematical logic	Elementary	Achievement	Authors qualitative argues
Coimbra <i>et al.</i> (2015)	N/A	AR an enhancer for math	13	Mathematical analysis	Undergraduate	Learning increase	Authors qualitative argues
Gutierrez <i>et al.</i> (2016)	Vuforia SDK	DiedricAR	50	Descriptive geometry	Undergraduate	Spatial ability improvement	Percentages
Cascales <i>et al.</i> (2017)	N/A	Augmented book	22	Money managing	Elementary	Achievement and Motivation	Wilcoxon test
Rohendi <i>et al.</i> (2017)	Artoolkit	AR geometry media	N/A	Geometry	High school	Prototype perception	Authors qualitative argues
Li <i>et al.</i> (2017)	Vuforia SDK	See me roar	2	Mathematics	Elementary	Prototype perception	Authors qualitative argues
Aulia and Muhimmah (2018)	Vuforia SDK	DorDor	140	Counting ability	Elementary	Prototype perception	Authors qualitative argues
Cai <i>et al.</i> (2019)	N/A	Seven, Super spaces, Magic coins	101	Probability and statistics	High school	Conceptions, approaches, and self-efficacy	ANCOVA
Gecu and Delialioglu (2019)	N/A	Augment	72	Geometric shapes	Preschool	Understanding	Mann-Whitney U and Wilcoxon tests
Ibáñez <i>et al.</i> (2020)	N/A	ARGE0	93	Geometry	High school	Achievement and motivation	ANOVA and ARCS
Our proposal (2020)	Vuforia SDK	SICMAR	103	Simple interest	Undergraduate	Motivation, achievement, technology acceptance	ARCS, Wilcoxon test, and TAM

2

3

Table 2 (on next page)

The first survey (Pre-test), and the first part of the second survey (Post-test).

1

Table 2. The first survey (Pre-test), and the first part of the second survey (Post-test).

General Data					
Name (s):			Surname:		
Age:					
Gender:			o (Male)		o (Female)
ARCS Professor			ARCS SICMAR		
Please think about each statement concerning the professor session you have just participated and indicated how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. Use the following values to indicate your response to each item: 1= <i>Not true</i> , 2= <i>Slightly true</i> , 3= <i>Moderately true</i> , 4= <i>Mostly true</i> , and 5= <i>Very true</i> .			Please think about each statement concerning the SICMAR you have just used and indicated how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. Use the following values to indicate your response to each item: 1= <i>Not true</i> , 2= <i>Slightly true</i> , 3= <i>Moderately true</i> , 4= <i>Mostly true</i> , and 5= <i>Very true</i> .		
Attention (A)	Mean	SD	Attention (A)	Mean	SD
A1. The quality of the materials used helped to hold my attention.	3.91	0.80	A1. The quality of the contents displayed helped to hold my attention.	4.19	0.93
A2. The way the information was organized helped keep my attention.	3.97	0.89	A2. The way the information was organized (buttons, menus) helped keep my attention.	4.09	0.90
A3. The variety of lectures, exercises, and illustrations helped keep my attention on the explanations.	3.98	1.04	A3. The variety of 2D models and interactions helped keep my attention on the explanations.	4.17	0.94
Total Attention	3.95	0.81	Total Attention	4.14	0.81
Relevance (R)			Relevance (R)		
R1. It is clear to me how the content of this lesson is related to things I already know.	3.35	1.02	R1. It is clear to me how the content of SICMAR is related to things I already know.	4.48	0.81
R2. The content and style of lesson explanations convey the impression that being able to work with is worth it.	4.05	0.92	R2. The content and style of explanations used by SICMAR convey the impression that being able to work with is worth it.	4.31	0.86
R3. The content of the lesson will be useful to me.	4.22	0.89	R3. The content about simple interest will be useful to me.	4.36	0.86
Total relevance	3.87	0.74	Total relevance	4.38	0.70
Confidence (C)			Confidence (C)		
C1. As I worked with this lesson, I was confident that I could learn how to compute simple interest well.	4.12	0.91	C1. As I worked with SICMAR, I was confident that I could learn how to compute simple interest well.	4.07	0.88
C2. After working with this lesson for a while, I was confident that I would be able to pass a test about simple interest.	3.54	0.94	C2. After working with SICMAR for a while, I was confident that I would be able to pass a test about simple interest.	4.08	0.92
C3. The excellent organization of the content helped me be confident that I would learn about simple interest.	3.96	0.83	C3. The excellent organization of SICMAR helped me be confident that I would learn about simple interest.	4.11	0.75
Total confidence	3.87	0.77	Total confidence	4.08	0.73
Satisfaction (S)			Satisfaction (S)		
S1. I enjoyed working with this lesson so much that I was stimulated to keep on working.	3.61	0.89	S1. I enjoyed working with SICMAR so much that I was stimulated to keep on working.	3.92	0.93
S2. I really enjoyed working with this simple interest lesson.	3.85	0.87	S2. I really enjoyed working with SICMAR.	4.07	0.92
S3. It was a pleasure to work with such a well-designed explanation.	3.95	0.82	S3. It was a pleasure to work with such a well-designed application.	4.31	0.89
Total Satisfaction	3.80	0.77	Total Satisfaction	4.10	0.83
Total ARCS	3.87	0.69	Total ARCS	4.17	0.66

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Table 3(on next page)

The third and fourth sections of the second survey (Post-test).

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Table 3. The third and fourth sections of the second survey (Post-test).

SICMAR TAM				
Please select the number that best represents how do you feel about SICMAR acceptance: 1=Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly agree.				
Perceived Usefulness (PU)	Mean	SD	Standardized Factor Loadings	Hypotheses Interpretation
PU1. I could improve my learning performance by using SICMAR	3.97	0.86	0.762	<0.01, Accepted
PU2. I could enhance my simple interest proficiency by using SICMAR	3.99	0.97	0.771	<0.01, Accepted
PU3. I think SICMAR is useful for learning purposes.	4.25	0.93	0.820	<0.01, Accepted
PU4. By using SICMAR, it will be easy to remember the concepts related to the calculation of simple interest.	4.17	0.97	0.832	<0.01, Accepted
Total Perceived Usefulness	4.09	0.80		
Perceived Ease of Use (PEU)				
PEU1. I think SICMAR is Attractive and ease of use	3.79	1.13	0.679	<0.01, Accepted
PEU2. Learning to use SICMAR was not a problem for me due to my familiarity with the use of technology.	4.32	0.97	0.805	<0.01, Accepted
PEU3. The markers detection was fast.	4.02	1.04	0.664	<0.01, Accepted
PEU4. The tasks related to controls manipulation were simple to execute.	3.92	1.04	0.817	<0.01, Accepted
PEU5. I was able to locate areas for conversions and calculations quickly.	4.19	0.86	0.792	<0.01, Accepted
Total Perceived Ease of Use	4.04	0.81		
Intention to Use SICMAR (ITU)				
ITU1. I want to use the app in the future if I have the opportunity.	4.28	0.96	0.925	<0.01, Accepted
ITU2. The main concepts of SICMAR can be used to learn other topics.	4.49	0.81	0.754	<0.01, Accepted
Total Intention to Use	4.38	0.82		
Total TAM	4.12	0.72		
SICMAR Quality				
Please select the number that best represents how do you feel about SICMAR quality: 1=Not at all, 2=A little, 3=Moderately, 4=Much, 5=Very much.				
Quality questions	Mean	SD	Standardized Factor Loadings	Hypotheses Interpretation
Q1. SICMAR showed all the concepts explained by the teacher.	4.45	0.84	0.450	<0.01, Accepted
Q2. The results obtained with SICMAR were correct.	4.24	0.82	0.562	<0.01, Accepted
Q3. The colors used for conversions were adequate.	4.17	0.91	0.527	<0.01, Accepted
Q4. The texts and numbers displayed by SICMAR were legible.	4.13	0.94	0.627	<0.01, Accepted
Q5. The size of the buttons allowed SICMAR correct manipulation.	3.16	1.22	0.531	<0.01, Accepted
Q6. SICMAR velocity of response to carry out the calculations was fast.	4.40	0.85	0.528	<0.01, Accepted
Q7. The illumination of the place was adequate.	3.79	0.98	0.513	<0.01, Accepted
Q8. The manipulation of the electronic device I use was straightforward.	3.76	1.00	0.676	<0.01, Accepted
Q9. Markers' manipulation was easy.	3.65	1.05	0.747	<0.01, Accepted
Q10. The manipulation of the device in conjunction with the markers was easy.	3.56	1.06	0.703	<0.01, Accepted
Total quality	3.93	0.62		

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Table 4(on next page)

Example of items included in simple interest practices.

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Table 4. Example of items included in simple interest practices.

Pre-test	Post-test
Isabel deposits \$5,000 in a bank account that offers a simple interest of 6% per year. How much interest will Isabel receive per month of deposit?	Calculate the simple interest on a loan of \$8,500 to pay in 91 days, with a simple annual interest of 18%.
What is the price of a cell phone that will be settled within three months? Please consider a payment of \$3,600 and the interest of 4.8% per year.	How much should Alejandro invest today, with an interest of 21% per year, if he wants to obtain \$15,000 within five months?

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Table 5(on next page)

Cronbach's alpha values computed for both surveys.

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Table 5. Cronbach's alpha values computed for both surveys.

Measurement	α
A	0.867
R	0.679
C	0.821
S	0.872
Total ARCS (pre-test)	0.934
A	0.847
R	0.776
C	0.814
S	0.889
Total ARCS (Post-test)	0.931
PU	0.877
PEU	0.859
ITU	0.815
Total TAM	0.921
Quality	0.839

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Table 6(on next page)

SEM fit statistics.

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Table 6. SEM fit statistics.

Fit indices	Value obtained
DoF	184
<i>P</i>	0.000
χ^2	386.726
χ^2/DoF	2.101
Goodness of fit index (GFI)	0.710
Adjusted goodness of fit index (AGFI)	0.635
Standardized Root Mean Residual (RMR)	0.080
Comparative fit index (CFI)	0.832
Normed fit index (NFI)	0.727
Incremental fit index (IFI)	0.836
Parsimony goodness of fit index (PGFI)	0.565
Root mean square error of approximation (RMSEA)	0.104

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Table 7 (on next page)

Path coefficients of the SEM proposed and its interpretation.

Table 7. Path coefficients of the SEM proposed and its interpretation.

Paths	Standardized factor loadings	<i>t</i>	Standard error	<i>p-value</i>	Hypotheses Interpretation
Quality->PU	0.694	2.487	0.247	0.013	H7 Accepted *
Quality->PEU	0.902	6.819	0.121	<0.01	H8 Accepted ***
PEU->PU	0.153	0.580	0.254	0.562	H9 Rejected
PEU->ITU	0.054	0.387	0.181	0.699	H10 Rejected
PU->ITU	0.830	5.301	0.211	<0.01	H11 Accepted***

*** p<0.001

*p<0.005

Table 8(on next page)

Direct, indirect, and total effects between the latent variables.

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Table 8. Direct, indirect, and total effects between the latent variables

Paths	Direct	Indirect	Total
Quality->PU	0.694	0.138	0.832
Quality->PEU	0.902	0	0.902
Quality->ITU	0	0.738	0.738
PEU->PU	0.153	0	0.153
PEU->ITU	0.054	0.127	0.181
PU->ITU	0.830	0	0.830

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