Chapter 3 System Design and Implementation

3-1 System Design

In this study, we designed integrated software, the name is Authentic-UG for students and Dashboard-UG for teachers. The web service can communicate using the RESTFUL API and xAPI protocols makes the design of the software designed to have a high level of scalability and a high degree of flexibility that allows this system can be used by other institutions even or other applications based on Augmented Reality. The software design can be seen in Figure 4, there are three main parts of the technology architecture that are a data source, web service, and consumer. In the data source section, combining internal source data created on the system with data source sourced from Google API, which is then managed in the web service section, then the data is processed in the second way with a web service that has sub-process data services that function for dynamic data management that can be changed, such as student data, institutional data, location-based question data and teacher data and sub-process learning services that contain several algorithm instructions to produce and process complex data from AR technology that is based on Authentic-UG such as accuracy on measurement system.
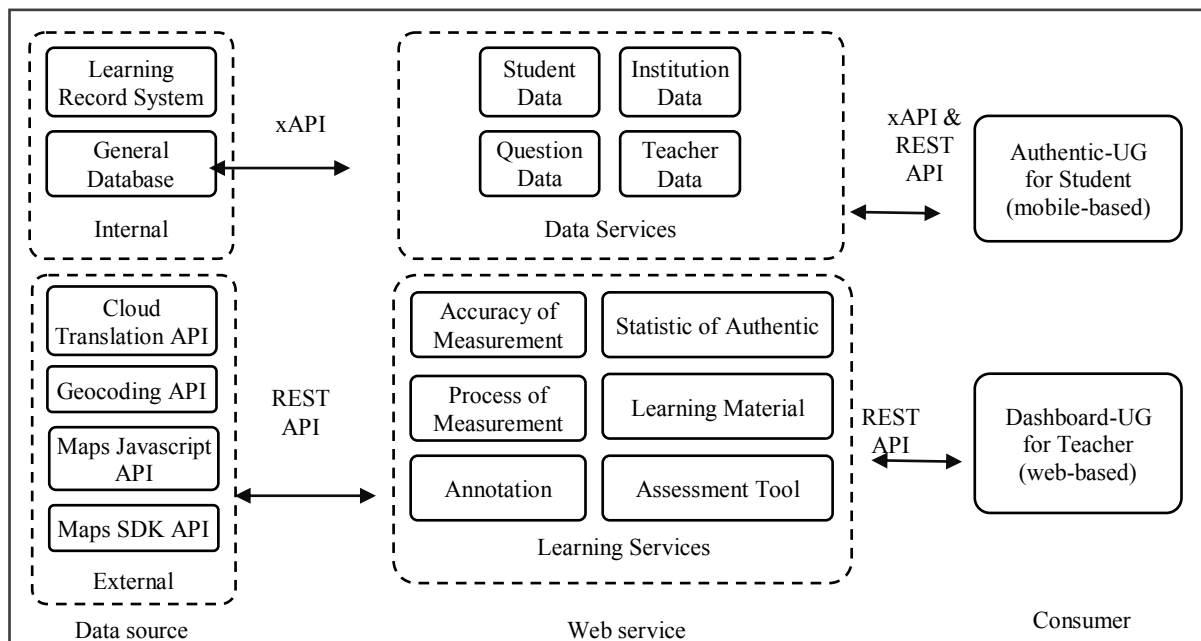

Figure 4. Technology Architecture

3-2 Implementation

Implementation for this study uses two types of applications, the application for students and the application for teacher. In this study, we focused on the students.

3-2-1 System Implementation for Student with Authentic-UG app

Authentic-UG is an android application with Augmented Reality technology that helps students learn on geometry topics with real experiences and more authentic. Figure 5 shows the difference in implementation of the Ubiquitous Geometry (UG) version one with Authentic-UG application that was developed by Hwang (2015). There are more new features in Authentic-UG, such as: using augmented reality technology implementation; can measure the length of line and the degree of angle with higher accuracy; can make lines and angle with a precisions of 3D model, easy and more comfortable to do measurement without any input from the user and can be used in real-time. In addition, the pedagogical aspects of learning activities students become more authentic because students must be able to solve questions based on location to search for authentic geometry objects and make measurements, there are peer sharing features based on location, assessment by teachers & students using scaffolding with three dimensions, and more topics on geometry learning materials..
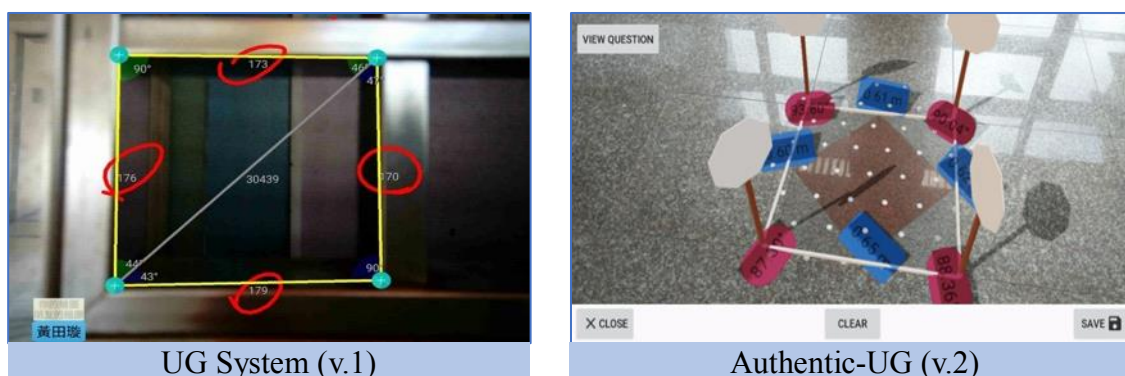

| UG System (v.1) | Authentic-UG (v.2) |

Figure 5. The difference implementation between version one and version two

The main feature of Authentic-UG is adopting Augmented Reality technology that can make angle and line measurements in real-time and has a high level of accuracy. The experiment to testing for accuracy of line by comparing the measurements of one of the buildings in the university area using Authentic-UG compared with using the map-based measurement application called Geo App that shown in Figure 6, while for testing for accuracy the angle compares Authentic-UG measurements with real-angle objects contained in the pattern on the floor shown in Figure 7 and the results of the summary test can seen in Table 2.

<div align="center">Authentic-UG App   Geo App</div>

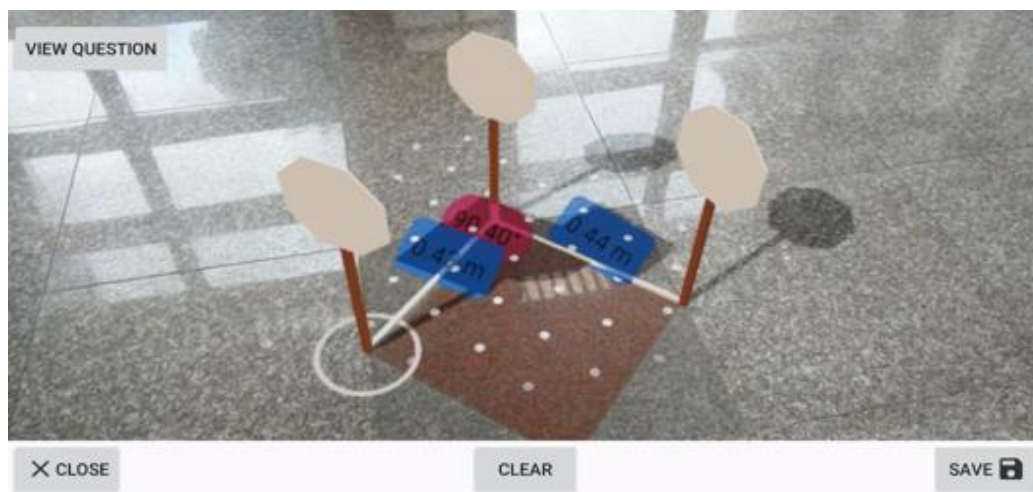Figure 6. Experiment for accuracy of line testing

Figure 7. Experiment for accuracy of angle testing

Table 2. The results of testing accuracy on Authentic-UG

Type of Accuracy	Method	Measurement results	Difference
Line	Authentic-UG	192.19 m	1-5%
	Geo-Measurement App	193 m (630.09 ft)	
Angle	Authentic-UG	90.40 degree	1-5%
	Pattern on the floor	90 degree	

In addition, for other features in the Authentic-UG application can be seen in Figure 8, such as: (1) there are five topic material consisting of 26 subtopics in geometry learning, (2) peer assessment using scaffolding assistance based on authentic results and the process video at the time of making and the teacher can also do assessment, (3) students can use maps to find authentic questions that are around their place or to see their records, (4) high accuracy of line and accuracy of angle, (5) with multimedia whiteboard features to annotate, and (6) students can measure using actual units indicated by 3D objects.

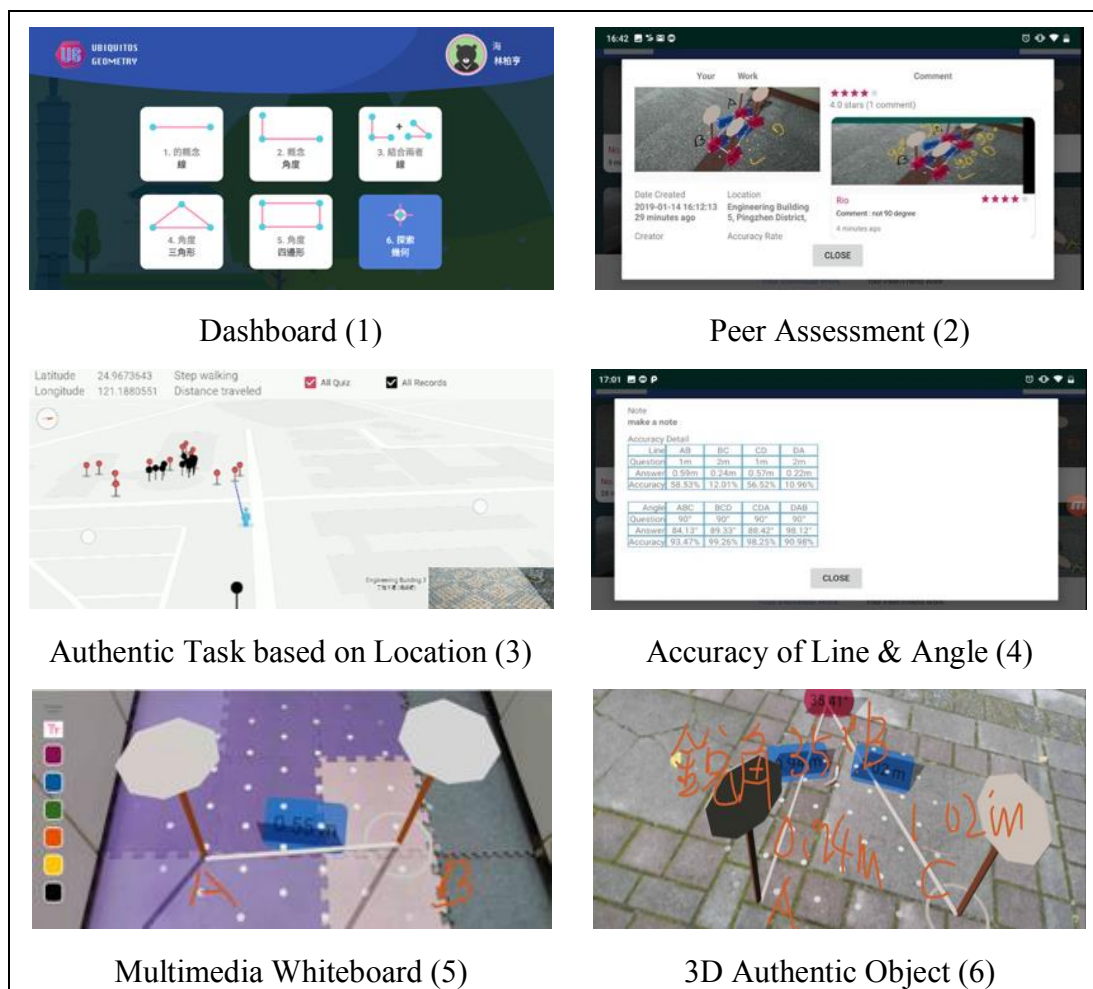| Dashboard (1) | Peer Assessment (2) |
| Authentic Task based on Location (3) | Accuracy of Line & Angle (4) |
| Multimedia Whiteboard (5) | 3D Authentic Object (6) |

Figure 8. Features on Authentic-UG

3-2-2 System Implementation for Teacher with Dashboard-UG

Dashboard-UG is a web application that can manage, monitor and analyze learning behavior that collected on the Authentic-UG application. The following is Figure 9 on the Dashboard-UG which can display interactive visualization so that the teacher can see the geometry learning process and the process of providing the assessment by the teacher.
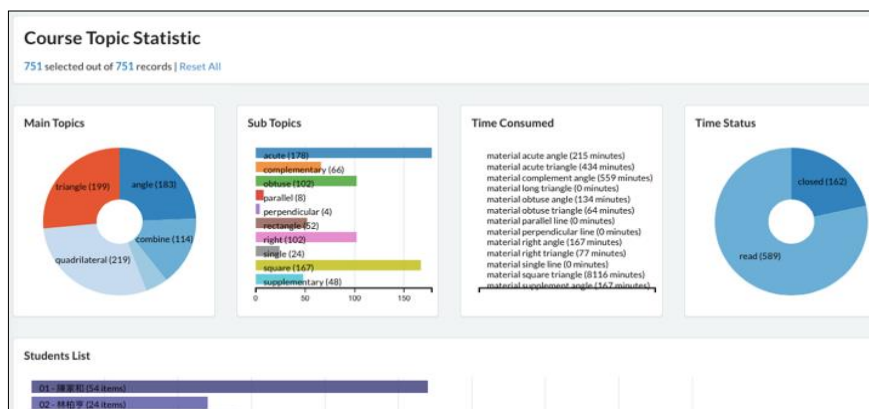

Figure 9. Student progress display on the Dashboard-UG

The features contained in the Dashboard-UG include: (1) the list of students with their activities; (2) see statistics such as the number of annotations, pages that are often opened; (3) learning time; (4) see student learning activities such as progress of each authentic of work made, comments between peers, accuracy that has been made, authentic of work results in the form of maps; and (5) features for teacher assessment.

The dashboard-UG has also passed through the testing using the white-box testing and black-box testing methods to ensure that the Dashboard-UG can be used properly according to the function of the predetermined scenario. The instrument used in the white-box testing uses the unit-test instrument and for the black-box testing method using the instrument user acceptance test (UAT). The test results shown in Table 1 show that the UG Dashboard has succeeded through 36 scenarios with a 100% success rate during white-box testing and successfully through 40 scenarios when testing using black-box which means that all features are based on the application UG web dashboard can work well.

Table 3. Test on the Dashboard-UG

	Method	Instrument	Tools	Scenario	Results
Webservice	White-box Testing	Unit Test	PHPUnit 7.5 & Xdebug 2.5	36 REST API	36/36 Pass OK
Consumer	Black-box Testing	User Acceptance Test (UAT)	Scenario	40 use-case of process	40/40 Pass OK

3-3   Learning Geometry using Authentic-UG

Learning activities in Authentic-UG application related to the school curriculum on mathematics subjects with different topics and authentic learning activities.

3-3-1 Learning Geometry

There are six topics of geometry learning material contained in the Authentic-UG application with different sub-topics. Students can choose geometry learning material according to the learning session at each meeting to learn to understand the kind of geometry guided by explanation and examples of geometry. Six geometry learning topics found in the Authentic-UG application include: (1) line concept topic with subtopics: single line, parallel line, perpendicular line; (2) angle concept topic with subtopics: acute angle, right angle, obtuse angle; (3) combine topic with subtopics: complementary, supplementary, (4) triangle topic with subtopics: acute triangle, right triangle, obtuse triangle; and (5) quadrilateral topic with subtopics: square & rectangle.

3-3-2 Learning Activities

Learning activities using Authentic-UG have several steps seen in Figure 10. First, the students choose topic and sub-topic that are in accordance with the agenda of the activity and the system will display learning material according to the choice of topics. After students read and see geometry examples on learning material, then students will get authentic problems that must be solved according to the location around them, and then students look for the closest object to solve the geometry problems that exist in the problem using the measuring and making authentic objects. After complete, students can add annotations and finally the results of authentic work can be saved and then conduct peer and teacher assessment.

Figure 10. Workflow for student learning activities on Authentic-UG

3-3-3 Measurement Skill in Authentic Context

Students' ability to measure and estimate on different topics is shows in Figure 11 that examples of student work on each topic. After that, students can add annotations using representative symbols with multimedia whiteboard.
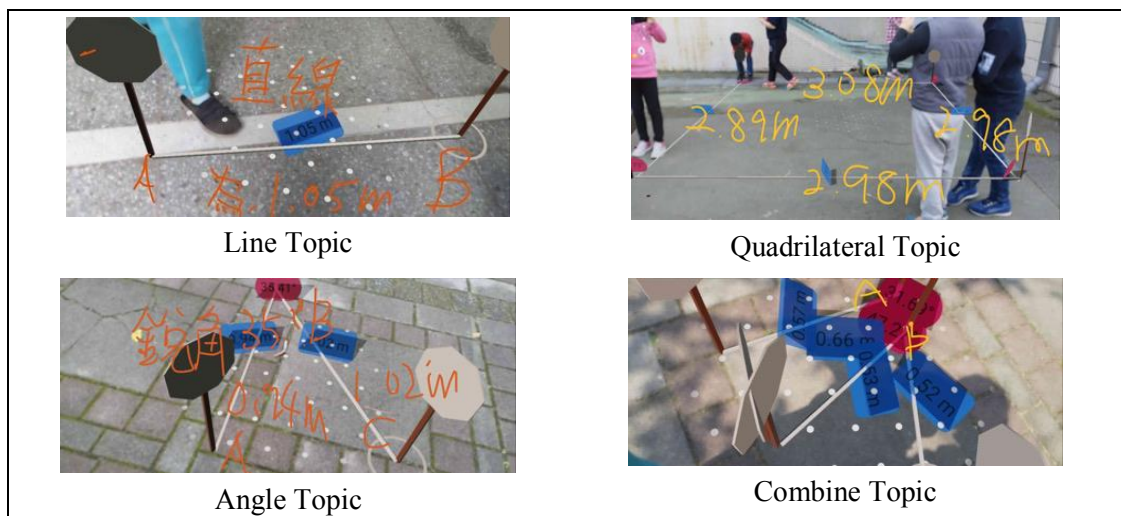

Figure 11. Examples of results of authentic work on different topics

3-3-4 Peer and Teacher Assessment

Assessment on students using the peer assessment sharing and comment mechanism with scaffolding assistance contained in the Authentic-UG application shown in Figure 12. Peer assessment is carried out based on the results of other students' work which can be seen of the work representations along with the process annotations and videos during production authentic of work and for assessment on teachers using the Dashboard-UG system shown in Figure 13.
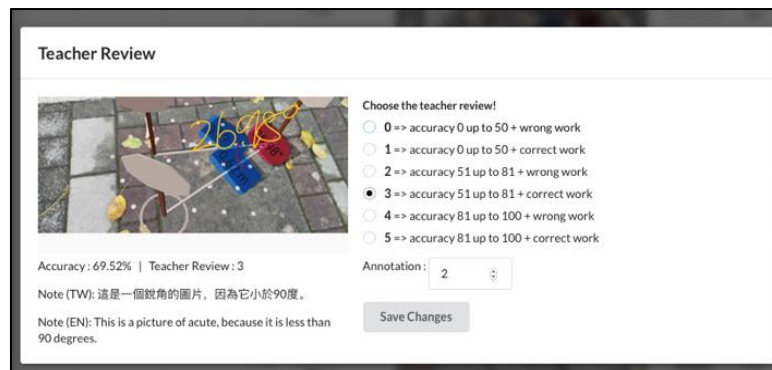

Figure 12. Peer assessment using scaffolding on Authentic-UG

Figure 13. Teacher assessment on Dashboard-UG