# Context-aware Assessment Using QR-codes

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***Abstract****: In this paper we present the implementation of a general mechanism to deliver tests based on mobile devices and matrix codes. The system is an extension of Siette, and has not been specifically developed for any subject matter. To evaluate the performance of the system and show some of its capabilities, we have developed a test for a second-year college course on Botany at the School of Forestry Engineering. Students were equipped with iPads and took an outdoor test on plant species identification. All students were able to take and complete the test in a reasonable time. Opinions expressed anonymously by the students in a survey about the usability of the system and the usefulness of the test were very favorable. We think that the application presented in this paper can broaden the applicability of automatic assessment techniques.*

## Introduction

Mobile devices, like smart phones and tablets, are changing the way we access Internet applications, thus opening new possibilities in the field of CBA. By using communication and computing capabilities of these devices, test can be delivered not just in the classroom but also in an open environment where students walk around a certain area and the selection of items to be delivered depends on the student's location and circumstances.

In this paper we present the implementation of a general mechanism to deliver tests based on mobile devices and matrix codes. The system is an extension of Siette (Conejo et al., 2004; Guzman & Conejo, 2005; Guzman et al., 2007).

To evaluate the performance of the system and show some of its capabilities, it has been applied in a real-world situation, namely in a second-year college course on Botany at the School of Forestry Engineering. During this course students received theoretical classes about different vegetal species, their anatomical and physiological description, their habitat, soil conditions, etc. They also took practical laboratory classes in which they were asked to recognize different elements in plants, which had been previously pressed and dried, or photographed. Some field practices were also performed in order to recognize living plants. Traditionally, course assessment was carried out by means of short essays and computer based testing with written theoretical questions and plant recognition from photographs.

An important goal of the course is that students acquire practical abilities to recognize living plants in the countryside, needed by professional practitioners. In order to develop such skills, students make field visits and afterwards fill in some questionnaires. Notice that theoretical knowledge is not enough to recognize a dried plant. Students should know where to look for it, finding the characteristic elements that differentiate that particular species from others. Moreover, recognizing pre-processed dried plants does not automatically imply recognition of a living specimen in the field. In many cases, some important classification elements are missing (perhaps there are no flowers, or the specimen is young and has different appearance, etc.), but there are other elements that help to distinguish and classify the specimen, like the location, soil, accompanying species, etc. Therefore, the initial challenge was to automatically assess the skills of students in species recognition of living plants during field visits, which is closer to engineering practice.

## Mobile learning and matrix codes

The expressions ubiquitous learning (u-learning) or mobile learning (m-learning) are becoming frequently used in present literature. However, there is some discussion about their exact meaning. The most obvious way to define the concept is in terms of the technology that supports learning activities. Thus mobile learning will be e-learning using mobile devices and wireless transmission, that is, learning delivered or supported mainly by mobile devices, such as smartphones or tablets. Moreover, some kind of context-awareness is needed for mobile learning applications. An easy way to achieve this is by means of matrix codes.

A matrix code, matrix barcode or 2D barcode is a two-dimensional way to encode symbolic information. It is the natural extension of traditional barcodes to the bidemensional space. There are several matrix codes (Kato & Tan, 2007). Among them, QR code is perhaps the most common in mobile applications, since it has an official standard (ISO, 2006) and can be freely used. QR code (Quick Response code) is a trademark of the Japanese company Denso Wave (a Toyota subsidiary). It can encode all types of data. In particular, it can encode a string and hence a URL. Cameras embedded in mobile devices and equipped with suitable software can detect QR codes in images, identify them as URLs, and automatically open the referred location in a browser. Most browsers for mobile devices integrate this QR software.

Matrix codes have been sometimes used in educational applications in the context of mobile learning. Summaries of such applications can be found in (Law & So, 2010; Ozcelik & Acarturk, 2011; Uluyol & Agca, 2012). Some of these applications are direct extensions of well-known ideas; for example, interactively displaying the results of catalogue searches at a library, or labeling student assignment submission sheets. A very interesting development is the integration of printed and on-line material accessed via QR codes and smartphones (Uluyol & Agca, 2012; Huang et al., 2012). On the other hand, few applications are documented that use matrix codes for outdoor learning. One of them is the Myst game platform (Laine et al., 2010). In this platform players must resolve a set of enigmas. The game area is divided into several subareas and each subarea has a unique set of enigmas related to it. 2D barcodes are used to provide context-awareness to the game so that enigmas and hints are presented just in the right subarea.

## The system Siette

Siette is a Web-based tool for managing and administering computerized tests. The system incorporates item banking, test building, delivery, and results presentation and analysis. It supports Classical Test Theory (CTT), Item Response Theory (IRT), and Computer-adaptive testing (CAT). It can also be used as an assessment tool integrated into an Intelligent Tutoring System (ITS), or linked to a Learning Management System (LMS) like Moodle as an external tool. It is currently used in three Spanish universities, i.e. the University of Malaga, the Polytechnic University of Madrid, and the Spanish Open University (UNED). It is domain-independent and used in several matters. Siette is available at http://www.siette.org. Siette provides two main sets of tools: and authoring tool and a test delivery environment.

The authoring contains a set of tools that allow teachers to create questions (commonly known as items in the psychometric literature), and define assessments (commonly known as tests) as a set of rules for selecting and delivering those questions to the students. For each course, the teacher defines a hierarchical structure of concepts. He can also create questions, which will be linked to the concept being assessed. Different kinds of questions are available in Siette, for instance, true/false, multiple-choice, multiple-response, fill-in-the-blank, and interactive questions supported by external applications or Java applets, which are transformed into polytomical item response models. Tests are geared towards the concepts to be evaluated and have several associated parameters. Some of these parameters are accessibility (i.e. for any kind of student, for grading purposes only in the university laboratories, etc.); solution displaying (never, at the end of the test, after each answer, etc.); an optional time limit; number of knowledge levels (i.e. the assessment scale); question selection criterion (adaptive, spaced repetition, topic weighted, fixed, etc.); and test finalization criterion (maximum number of questions, maximum time, maximum estimation accuracy, user decision, etc.)

From the student's point of view, Siette is a virtual classroom where tests are delivered. Tests can be used for grading or for self-assessment (Guzman & Conejo, 2005; Guzman et al., 2007). In the case of self-assessment, tests permit students to trace their progress in the learning process. They can also combine hints with the question stem, and feedback with the correction, in order to remediate misconceptions or reinforce well-acquired knowledge.

# A mobile testing system based on matrix codes

As noted above, matrix codes can be used to represent any string, in particular a URL (notice that in the following we will always use the expression ”QR codes”, since these have been used in our application). So, the main idea is to attach different QR codes to different places. By coding a question identifier inside a QR code, access to that question can be controlled by the recognition of the corresponding QR code. In the following we will refer to those questions as ”QR code questions”, to differentiate them from usual, non-QR Siette questions. QR codes questions can be used indoors and outdoors. However, if QR codes are used outdoors, it is also necessary to provide the geographical location of the questions, because the user will need to know where they are located in order to get there to answer them. To accomplish these new functionalities the following features should be added to Siette: (1) An easy-to-use authoring tool for the teacher to define a question, associate it to a location and generate the corresponding QR-code; (2) Access control to each question based on the QR-code. (3) A modification of the question selection mechanism from the item pool, forcing a question to be posed when its QR code is scanned. (4) An easy-to-use tool that allows student to find out where the questions are located. If questions are restricted to be posed at a certain location, students should know where they are located; otherwise they could never get certain questions.

Since Siette is based on the concept of item pool, it should be taken into account that the same question can be used by different tests. Moreover, Siette already has many different options, like different item types, question-sequencing criteria, scoring procedures, etc. It would be desirable to include this new feature in a way that could be compatible with as many pre-existing components of Siette as possible.

## Preparing the test

First of all, the teacher has to define the set of questions by using the Siette authoring tool; at this point there is no difference from usual, non-QR questions. Any type of question supported by Siette and the client device web browser can be used. Stem, responses and attributes of the question are edited in different tabs. New fields have been added for the location information in the tab “Selection”. It now requires entering the exact latitude and longitude of the point where the question can be posed. Of course these numerical data are not easy to know, and it would be a burden for teachers to enter them directly. To make the work easier, a pop-up framework has been defined. It connects to the Google Maps API and allows visual edition of the location. Geographical coordinates can be obtained just by clicking on a point, or entering an address and searching for it (see Figure 1). By clicking on the QR button, a pop-up window with the QR code appears.

From a technical point of view, the location framework is an HTML page that contains some Javascript code that calls Google Maps API1. The API is used to find out location coordinates. It also allows searching for a given address and retrieving the current location. On the other hand, QR codes are generated by calling the Google Chart API2. Generated QR-codes contain an URL that includes the question-id as a parameter.

When a set of questions has been defined, the teacher should also define a test by giving a set of criteria for question selection and sequencing, and other attributes like time constraints, scoring procedure, etc. There is nothing special at this point. A test could contain both QR-code questions and non QR-code questions. It is also possible to use the same question in different tests.


**Figure 1: The SIETTE authoring tool. Pop-up frames for location and QR-code**

Siette editor includes a tool for searching all the questions and generating a sheet containing all the QR codes, in order to make things easier for the teacher. This tool makes it also possible to attach some extra parameters to the QR code, like test id, access mode, etc. Alternatively, the teacher can create a QR code for test initialization (this feature can be useful if the same questions are used in different tests) and generate QR codes for the questions without assigning them to any particular test.

## Taking the test

Tests with QR-code questions are accessed in the same way as any other tests in Siette. Using the web browser of a mobile device, the user has to login, select a subject and select the test to be taken. Direct access to a given test can also be granted using a QR-code for that test. In this case, Siette requests the user name and password, and redirects the user to a page with information about the test to be taken. When a test is started, a cookie is sent to the client browser to identify it for future requests.

From the server side whenever a new question is requested there are two main cases: (1) The test is requested to pose a given question, defined by its internal question-id. This is the case of a QR code question that has been scanned by a user. In this case, Siette validates that the question-id corresponds to a valid question in the test, and that the test session has already been started. If that is the case, the question is rendered and posed to the user browser. If the test has not started yet, the user is redirected to the login page, or directly to the starting page. (2) If no specific question is required, Siette just follows its normal behavior, selecting a question out of the question pool available for the test at that stage. However, the list can be eventually empty. Then, Siette checks if there are QR code questions available for that test, constructs a web page with the location of those questions, and sends it back to the user as a response. If no QR code questions are available, the test ends.

In order to take a test, the user should use two applications that are commonly integrated into a single one in mobile devices: a web browser and a scanner for QR codes. First of all, by using a QR code that includes the test-id, the user requests to begin a test. As a result, that action produces the test initial page. Using the web browser, the user requests to begin the test and asks for the first question. Siette tries to find it using the procedure described above. If no questions are available except those controlled by the QR code, the waiting page is generated and presented to the user. Then the user should locate a QR code corresponding to one of the questions and scan it. Scanning the code generates a request for the question that is returned as a web page. The question should be answered using the web browser, and sent back to the systems that automatically produce another request for the next question. This new request makes the system construct a new waiting page (showing just the remaining questions), which is presented to the user. The process described above may be a little different if the first call includes also a question-id. In that case, when the test begins the first question is presented instead of the waiting page.

Figure 2 shows the sequences of screenshots of web pages presented to a user. Reading from left to right (1) The user scans the QR code containing the reference to the test. (2) The login page is presented. (3) The user is redirected to the test initial page. (4) The test begins, and it shows the waiting page with a map that show where the questions are located. (5) User scans the code of a question. (6) The question appears in the web browser. (7) The answer is sent to the system and a new waiting page is presented. The previous question has already been answer, so it is removed from the map. (8) The user scans the second QR code. (9) The question is posed and the user sent back its response. The test has been taken using an iPad with a commercial application called "Scan". Notice that the order in which questions are posed depends on the track followed by the user.

**Figure 2: An example of the test delivery process**

## Mobile testing for a Botany course

In order to show the potential of these ideas and verify the functionality of the implemented software, we have designed an experiment for a case study. The experiment was carried out by 28 volunteer students of the Escuela Tecnica de Ingenieros Forestales (Forestry Engineering School) of the Polytechnic University of Madrid. The experiment took place at the end of the semester, when it is assumed that all students have mastered the material.

One of the more relevant skills in the study of Botany is plant recognition. In order to acquire this skill, different steps should be covered. Initially, students have to memorize and assimilate static knowledge about the plants. They should practice this knowledge with photographs and dried plants. These learning activities have some advantages: plants from different geographical locations can be collected into the same place, and this place is always accessible, thus speeding up the learning process. However, there are also some limitations to using photographs and dried plants. For example, in dried plants color information is almost always lost; moreover, the student can only interact with a limited fragment of the plant that has been removed from its natural environment. While photographs do not cause such problems, they are also limited in that they show only one or two details of the plant, or perhaps a general view where details are missing. Combination of photographs and dried plants are a good workbench to acquire plant recognition skills, but it is not enough. Living plants collections and field visits are needed in order to develop actual skills. Time and economic costs imply that the number of visits during the course is not sufficient. On the other hand, final assessment of the skill is based just on the first stages of learning (dried plants or photographs). Practical reasons make it difficult to achieve assessment in real-world situations.

By using the system described in this paper, we have tried to develop a tool for formative and summative assessment. On the one hand, attaching QR code questions to living plants will allow a long-term mechanism to include practicing in real conditions without teacher supervision (formative assessment). QR code questions will be helpful in recognizing plants at different stages of development: birth, blooming, fructification, etc. On the other hand, assessing students' performance with living specimens allows evaluating their actual professional skills (summative assessment).

The experiment consisted of two tests: T1. A classical test delivered with Siette, containing questions about plant recognition based on high definition photographs. T2. A location-aware test, using QR codes attached to living specimens of plants at the Arboretum of the Forestry School.

Each test contained 10 questions, randomly selected out of a pool of 20. This randomized selection was designed to avoid cheating and intra-subjects communication, especially in the location-aware test that was taken in an open environment. A classical test was taken by the 28 students in a computer room. The location-aware test was taken independently by 4 students at a time, using the 4 available iPads. Correct answers were not shown until the end of the second test so as not to interfere between tests. In all cases the expected answer was the scientific name of a plant. In the classical test the questions include a brief description of the plant's appearance and habitat. In the location-aware test a QR code for each question was located beside a living plant, and the stem contained only the habitat description but neither the written description of the plant nor its photograph.

When students began to take T2, the system displayed a map with question locations. They initially walked in the direction indicated by the teacher, who distributed them so as to prevent them from communicating. Whenever a student found a QR code attached to a plant, she scanned it using an iPad application, and the question appeared on the iPad screen. Then she answered the question and a new map was displayed containing the location of the remaining questions. The student continued until she reached the maximum number of questions.

**Table 1: Summary of results in T1 and T2 tests**

| | | |
|---|---|---|
| Number of students | 28 | 28 |
| Number of questions | 10 | 10 |
| Average score (std. dev.) | 43.92 (21.14) | 62.14 (20.79) |

| | | |
|---|---|---|
| Average time spent in minutes (std. dev.) | 10.29 (4.10) | 11.27 (4.92) |

Test results are shown in table 1. A paired t-test indicates that T2 score is higher than T1 score, ($p<0.0001$). Almost all students increased their scores. T2's duration is a little longer than T1's (however, the difference is not statistically significant) which is not surprising given the time spent on scanning the codes and moving from one site to another. Pearson correlation between both tests was 0,28. This low correlation is mainly explained by the differences in the scores of the low level students, as can be seen in Figure 9 where the major differences concentrate. On the other hand correlation between time spent in T1 and T2 is high (0,76).

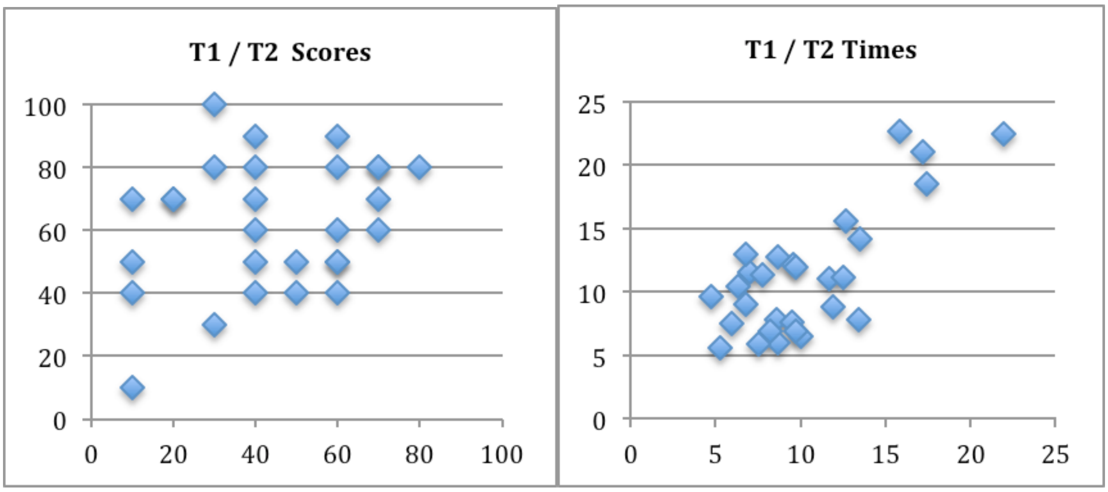


**Figure 3: Score and time spent (in minutes)**

One of the aims of this experiment was to evaluate the system's performance in a real-case application, and to find out the users' perspective. The first conclusion is that the system has worked properly, because all students were able to complete the test in a reasonable time. In order to know the users' point of view, a survey was carried out. The Appendix shows the results of this survey. It was anonymous and not compulsory. It was answered by 22 students. Some important questions were asked twice, changing the expression in order to check consistency. All questions were answered using a 1-5 Likert's scale. Depending on the question, 1 means "none", "very low" or "completely disagree", and 5 means "all", "very much", or "completely agree". Results are given with the mean and standard deviation.

The overall evaluation of the use of the system and the usefulness of the activity was very positive. All of the participants responded to the question about "Overall evaluation" with a value above 4 in the 1-5 Likert scale, with an average of 4.36. This is especially significant if we take into account that some of them declare no previous use of iPads or smartphones.

Another interesting result is that almost all of the students completely agree that doing the test with living plants is better than with the photographs (4.86 in the 1-5 Likert scale), and that this type of assessment is appropriate both for formative (4.73) and for summative assessment (4.50).

At the end of the survey there was a section for free comments from students. Most were positive and suggested different improvements, like providing hints and feedback with questions, the possibility of going back and forth when answering questions, including optimal path in the map, and even distributing the QR codes in all city gardens and parks. In fact, hints and feedback are part of the Siette system, but were not included in this experiment because we wanted to study a pure assessment situation. Allowing back and forth answering might be a new feature but it is doubtful that it would be practical in the case of geographically distributed questions.

On the other hand, some students pointed out that the Internet connection was slow and maps take a while to be downloaded (someone also proposed to distribute printed maps as an alternative). Some complained about scarce availability of mobile devices and the extra time spent on taking the test.

# Conclusion

Mobile devices, like smart phones and tablets, provide new opportunities for the development and use of educational software. In this paper we have described the design, implementation and evaluation of an application of mobile learning to the problem of test definition and delivery. The application is a natural extension of the Siette testing system, now equipped with the capability of dealing with QR codes.

To evaluate the performance of the system, it has been applied in a real educational situation. We have developed a test for a second-year college course on Botany. Students were equipped with iPads and took an outdoor test on plant species identification. Every question was identified by a QR-code. Our first conclusion is that the system is technologically robust. All students were able to take and complete the test in a reasonable time. From the point of view of usability and usefulness, opinions expressed anonymously by the students were also very favorable.

We think that the application presented in this paper broadens considerably the applicability of automatic assessment techniques. With this technique, testing can be performed in scenarios more similar to those found in real-world situations. Future work along this research line will include the development of new mechanisms for student location and question triggering, based on Wi-Fi and/or GPS positioning. This would complement the work described here. In addition, we are working on a Siette client native application for iOS. The main problem faced in that case would be the location precision (which is greater than 100 m for Wi-Fi/3G and greater than 10 m for native GPS). Using QR code this problem is completely avoided even for indoor use.

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