Journal of Universal Computer Science, vol. 23, no. 12 (2017), 1147-1171
submitted: 20/3/17, accepted: 27/8/17, appeared: 28/12/17

Development and Evaluation of a Model-Driven System to Support Mobile Learning in Field Trips

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Abstract: While field trips promote the scientific spirit of students by increasing their ability of observation and discovery in various areas of knowledge, the introduction of ubiquitous technologies, such as sensors and actuators, during the field trips, improves students' motivation and learning. However, the development of systems for this purpose implies to deal with the seamless treatment of the devices heterogeneity, absence of fixed communication infrastructure, dynamics of the computational elements of the environment, and support for user mobility. This paper presents then the development and evaluation of a system, called Ubiquitous Field Classes Inventor (UFC-Inventor), which aims to promote the use of mobile and ubiquitous technologies in field trips. The UFC-Inventor evaluation is performed in two stages: first, with five teachers of natural sciences; and later, during a field trip with seventeen students. Two of the teachers were from higher education (Geology and Animal Science) and three of them from high school (two in Geography and one in Biology). The seventeen students who participated in the case study were undergraduate students in the third year of their Geology course. The results suggest a good acceptance of UFC-Inventor and indicate that its execution occurred correctly.

Keywords: Model-driven Development, Ubiquitous Learning; Cross-Platform Generation Field Trips; Geology
Categories: L.7.0, L.3.0, D.2.2

1 Introduction

The field trip (or field class) is an educational activity that provides diverse benefits to learn, for instance, to increase the capacity of observation and discovery of students. Many researchers characterise the field trips as a motivating activity that allows students to experience in practice what has been taught in the classroom [Shakil, 11]. Nevertheless, during field trips, students and teachers face obstacles that may prevent the benefits of these educational practices [Roslin, 13; Shakil, 11]. In certain

[1] CNPq's DT-2 productivity researcher

situations, students are burdened with many activities. For example, during a Geology field trip, students must analyze and record the environmental information, take notes of the teachers' comments, perform group activities with other students, and carry several devices (e.g. GPS, compass, digital camera, field notebook).

Mobile and ubiquitous technologies have been used to help students in learning activities during field trips [Chiang, 14; Chin, 13; Hwang, 16]. In this work, we used the term Ubiquitous Field Classes (UFC) to name educational practices, which occur in the field with the support of mobile and ubiquitous technologies. The integration of ubiquitous computing resources in the field trips provides exciting possibilities for teaching and learning processes. We can mention the following: identifying the student's context for delivering content according to his/her situation in the field (e.g., location, nearby objects); recording the actions and preferences of learners for future recommendations; using sensors to collect relevant information to learning; and helping communication via wireless networks between class participants [Giemza, 11; Marçal, 14; Wu, 13; Karahoca, 16].

However, the development of ubiquitous systems requires a good level of programming skills. Also, it imposes some challenges inherited from its distributed systems nature. For instance, programmers must deal with the treatment of heterogeneous mobile devices and the support for user mobility. Additionally, in the field trips, the absence of fixed communication infrastructure is frequent, and the environment is highly dynamic [Sousa, 16; Hwang, 14; Maia, 09]. Besides, each field trip varies according to location, participants, and teacher's goals in that environment [Behrendt, 14]. Thus, the use of mobile and ubiquitous technologies in field activities requires solutions adapted to specific learning contexts.

In summary, the central problem addressed in this research is how to offer the potential of Ubiquitous Computing to field trips without requiring advanced programming knowledge from teachers and university professors.

An approach to the development of systems that abstracts the complex aspects of programming and facilitates software customisation is the Model-Driven Engineering (MDE) [Brambilla, 12]. Using MDE tools, it is possible to represent domain concepts with high-level models and automatically generate systems through transformations between models. Systems of different areas of knowledge have yet been built using MDE technologies [Cuadrado, 14; Hermida, 13; Blanco, 14]. Regarding the application of MDE in education, we highlight authoring tools that facilitate the construction of educational applications, such as Lemonade, MAT for ARLearn, Midgar, and App Inventor [Giemza, 11; Tabuenca, 14; García, 14; Xie, 15].

This paper presents the development and evaluation of a model-driven system to support the use of mobile and ubiquitous technologies in field trips: Ubiquitous Field Classes Inventor – UFC-Inventor. With that tool, teaching professionals can create graphical models of their field classes and, from it, generate ubiquitous cross-platform applications to be used by students.

This work is a result of research that we started in 2011, whose goal was to evaluate the benefits and the best ways to deploy and promote the use of mobile and ubiquitous technologies in field trips [Viana, 11]. In fact, first, we conducted a systematic mapping study with papers on experiences on the use of ubiquitous technology in education. From this survey, we identified requirements for ubiquitous field classes. After, we developed UFC Inventor and its main components: ML4UL

(Modelling Language for Ubiquitous Learning), the UFC-GLM graphic tool; and, the UFC-Generator system, which generates the final mobile applications.

We evaluated our approach with students and teachers having in mind the following research questions:

RQ1 - Would natural science teachers be able to use UFC-Inventor to build applications with ubiquitous computing resources to be used in field lessons?

RQ2 – In a real field trip, what are the students' perceptions of the usefulness and ease of use of an application created with the UFC-Inventor?

2 Background

A widely used way to motivate students is using new technologies and different types of media. In this scenario, Mobile Learning (m-Learning) emerges as new technology that uses mobile devices (e.g., mobile phones, smartphone, palmtops) during the learning process [Zydney, 16; Land, 15; Looi, 15]. This paradigm assumes the mobility of students and offers access to content on their mobile devices. Students can even use computational resources at the time and place in which the educational practice happens [Fulantelli, 15]. The m-learning paradigm arose from the possibility of using the ready availability of mobile devices to tend to some specific education and training needs. The m-learning goals include: provide access to educational content at any time and anywhere; promote formal and non-formal learning; expand the boundaries of the classroom; and enable the development of innovative methods of teaching using the new technological resources [Marçal, 05] [Laru, 15]. Mobile learning can also help to reduce some of the formality involved in traditional learning methods, making it more convenient for students (young people, especially) [Chen, 13]. Additionally, mobile learning allows for mobile devices to be used by adults, who are resistant to technological change, thus involving them in this new era of experience with mobile learning [Chen, 13].

Sharples and Rochelle divide m-learning into three phases [Sharples, 10]. The first one is characterised using mobile devices in the classroom. The second considers the students' mobility and the devices beyond the walls of the schools. Finally, the third phase is marked using resources of Ubiquitous Computing in favour of teaching and learning, known as Ubiquitous Learning (or u-learning). Laru et al. went further and divided the research on the educational use of mobile technology into four stages [Laru, 15]. They argue the mobile learning research is in the Plateau of productivity phase according to hype cycle research methodology, which indicates its use is now mature and the mainstream adoption started.

Hwang, Tsai, and Yang use the Context-aware Ubiquitous Learning term to refer to the use of mobile devices with wireless and sensor technologies in learning activities [Hwang, 08]. Our work adopts this definition, given our research involves the use of sensors of mobile devices in field trips.

2.1 Ubiquitous Learning Applications in Field Trips

We carry out a systematic mapping with papers published between the years 2010 and 2014. Our goal was to identify requirements for ubiquitous applications in field trips [Marçal, 15]. Figure 1 shows the profile of the ubiquitous applications for field trips identified from the analysis of the papers surveyed. The majority part of applications is in natural sciences. Their primary operating system is Android, and location information is the most used student's context element. M-learning applications highlight the assimilative and productive activities, with consultation and recording of information remotely.

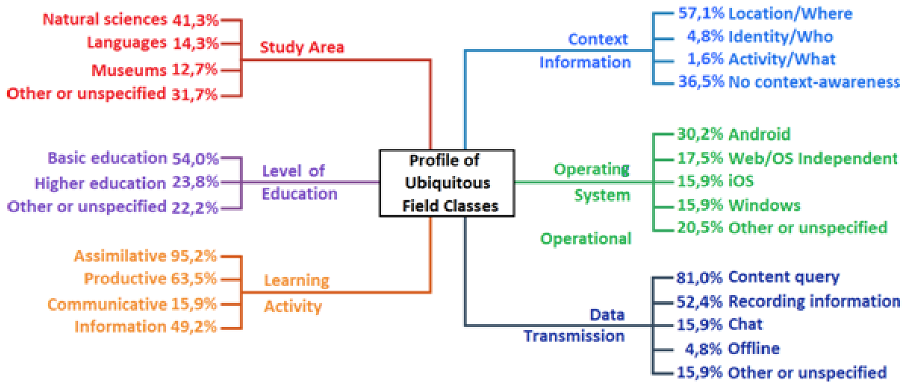

Figure 1: Profile of Ubiquitous Field Classes

Table 1 lists the recurrent and most common requirements, grouping them into functional and non-functional. Concerning the non-functional requirements, context-awareness stands as a valuable resource, and it was present in most of the studies (63.5%). The use of multimodal interfaces [Oviatt, 03] was another important feature identified. They facilitate the comprehensibility of the systems and avoid extensive training [Cohen, 15].

Requirements of ubiquitous field classes	
Nonfunctional	**Functional**
Context awareness	Provide multimedia content
Multimodal interface	Register the material produced by the students
Sensor use	Enable wireless interaction among students and teachers.
Compatibility with mobile devices	Allow download educational content from a remote server.
	Save the registered information on a remote server.

Table 1: Nonfunctional and functional requirements of ubiquitous field classes

The sensors on mobile devices (embedded or attached) are also critical non-functional requirements identified in the survey. Furthermore, field trip ubiquitous applications should be compatible with the students' mobile devices. Regarding the functional requirements, the papers we surveyed indicate that ubiquitous applications for field trips should allow the registration of information locally and on a remote server. The u-learning applications should also provide multimedia content (e.g., text, images, and audio) and wireless interaction tools between students and teachers.

2.2 Related Work

We find systems with similar solutions to the one presented in this paper. Table 2 summarised them. We used eight comparison criteria. The first four are related to the authoring tool:

i. Does the project of the educational practice use a graphical model?
ii. Can users without programming knowledge operate the system?
iii. Does the solution adopt an open model of design specification?
iv. Are the projects created able to be shared and used by other authors?

The last four are related to the mobile application:

v. Which are the supported mobile operating systems?
vi. Which sensors can the user add to the project of the educational practice?
vii. Do the generated apps require access to the Internet all the time?
viii. Does the proposed authoring tool provide features for user interaction by using wireless technologies?

	Lemonade	**MAT for ARLearn**	**Midgar**	**App Inventor**
i. Graphical modeling	Yes	Yes	Yes	Yes
ii. User without programming skills	Yes	Yes	Yes	No
iii. Modeling with open specification	No	No	No	No
iv. Project sharing	No	Yes	Yes	Yes
v. Mobile Operating System	Windows	Android	Android	Android
vi. Sensors used	GPS	GPS	Depends on the server	GPS, NFC, Compass and Accelerometer
vii. Connection dependency	No	Yes	Yes	No
viii. Wireless interaction	No	No	No	Yes

Table 1: Authoring Tools for ubiquitous applications

These criteria are a mix of the required features for authoring tools presented in [Tabuenca, 14] and the requirements of ubiquitous applications for field trips mentioned in the previous section. Not all solutions are focused on users without programming knowledge (ii., User without programming skills). Moreover, the systems do not adopt an open specification model for the classes specification, like SCORM or IEEE LOM, which allow interoperability with other tools (iii. Modeling with open specification). Not all solutions allow users to share the projects created with other users (iv. Project sharing). Regarding supported operating systems (v. Mobile Operating System), the solutions are restricted to a single platform: Android or Windows Phone. All solutions include the use of sensors, especially GPS (vi. Sensors used). Some of the systems generate applications requiring an Internet connection, which can preclude their use on certain field trips (vii. Connection dependency). Only the App Inventor generate applications with features for wireless communication between users (viii. Wireless interaction).

3 UFC-Inventor

3.1 Implementation

In this research, we follow the Co-Design Methodology taking into consideration the multidisciplinary composition of the team, which included two geologists and geology teachers, three computer science researchers, a system analyst, a programmer, and a graphic designer. The software development process followed the five phases proposed by the Co-Design Methodology [Millard, 09], with some adaptations. Figure 2 illustrates the core steps adopted.

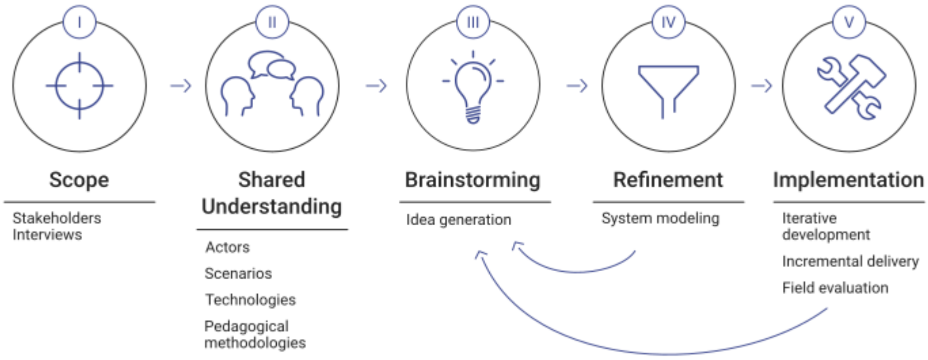

Figure 2: Development process adapted from Co-Design Methodology

I. Scope. In this phase, an overview of the objectives of the system was defined, highlighting the aspects related to the learning activities during the field trips. Another important task was to ensure the involvement of all stakeholders related to the problem domain.

II. Shared Understanding. In this phase, the stakeholders shared their experiences and expertise, such as application scenarios; the types of mobile and ubiquitous technologies to address; and pedagogical methodologies that could serve as a basis for the implementation.

III. Brainstorming. In this phase, it was possible to outline the first interfaces of the UFC-Inventor, considering the actors, scenarios, technologies and pedagogical methodologies identified in the previous stage. With this, stakeholders had artefacts closer to the final system to collaborate with suggestions.

IV. Refinement. As the application design was gaining a final appearance, the project team completed the requirements assessment and the project modelling diagrams (e.g. Use Cases, Class Diagrams, and Activity Diagrams).

V. Implementation. After the definition of the documentation, the programming team started the iterative development of the UFC-Inventor with incremental deliveries. It is important to note that phases III, IV and V occurred in sprints, allowing the correction of identified errors in the previous steps. After elaborating a version with no apparent errors, we have proceeded to the user evaluation phase.

3.2 Main features

UFC-Inventor is a system developed to support mobile learning in Field Trips. It allows the authoring of mobile applications with ubiquitous computing resources. Figure 3 shows an overview of our approach. Our target audience is teaching professionals without programming knowledge (e.g., teacher, area specialist). UFC-Inventor creates applications compatible with three operating systems (e.g., Android, iOS, Windows Phone). These mobile apps provide field trip support, without the need for Internet connection all the time. UFC-Inventor has three main components: the UFC-GLM, a graphical modelling tool of field trips; the ML4UL language (Modelling Language for Ubiquitous Learning), which is an open specification to represent ubiquitous field trips; and the UFC-Generator module, which generates multiplatform applications.

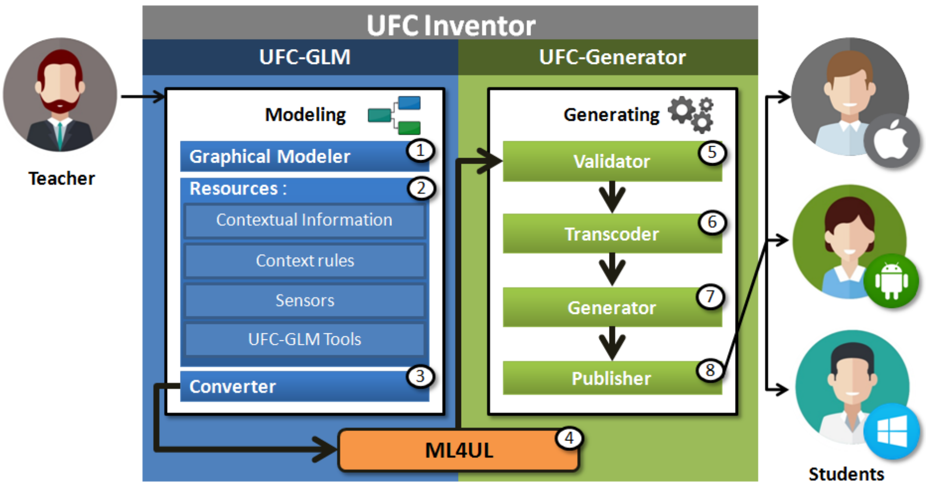

Figure 3: Overview of the UFC-Inventor

The UFC-GLM is a desktop system for Windows. Its interface is divided into four parts. The central area is used to model the field trips graphically. In the top part, users will find the textual menu with quick access buttons. In the right side, the component palette allows building field trip diagram and templates. The bottom part contains the symbols that represent the participants of the class, as the teacher and the student. With UFC-GLM, teachers model the learning activities and the flow that they should happen in the field trip. Teachers also include the ubiquitous computing resources in the class project, such as sensors and wireless communication. The tool converts the visual model developed to a specification in ML4UL format. Users can write rules to create adaptive classes in which content and activities are sensitive to the student's context (e.g., location). The UFC-GLM supports the recording of photos and audios, and their annotation following a context-aware multimedia annotation approach [De Andrade, 16] [Viana, 14]. It also offers a chat service via Bluetooth. Figure 4 shows the main screen of UFC-Inventor. A palette with the connection options for the lesson model is on the right side. The screen centre shows the authoring environment with an example diagram, which illustrates the use of some multimedia features. Templates screen, on the lower right side, contains a template ready to be reused. At the bottom, the user can set the types of users allowed in that class (in this example teacher and student).

When class modelling, the user exports the project in the ML4UL format. The Modelling Language for Ubiquitous Learning consists of a domain specific language (DSL) specialised in ubiquitous applications for field trips. It was extended from the IMS Learning Design specification[2], with the main objective to answer the requirements identified in Table 1. ML4UL adds to IMSLD the following specific elements for ubiquitous applications: *<sensor>, <sensor-property>, <contextaware-activity>, <local-conference>, <sharing>, <media-capture>, <local-database>, <object-store> and <synchronization>*. The project of a class in ML4UL consists of: an XML format file containing the specification of the field trip (manifest); and the files the tool requires for execution of the planned learning activities, such as text, images, audio, and video.

With the file in ML4UL format, the user accesses the website of the UFC-Generator. Then, she selects the exported file, the mobile operating system to which she wishes to generate the application and its visual style. With this data, UFC-Generator performs several steps, as illustrated in Figure 3. First, the specification must go through a validation step (5), in which the tool reads the input file, and checks its compliance with ML4UL. Subsequently, the transcoder (6) transforms the specification of the field trip from ML4UL to the source code in a specific language. For the implementation of the UFC-Generator, we adopted the Apache Cordova platform[3], which works with HTML5, CSS and JavaScript formats. After the creation of the source files, the generator (7) runs the Cordova compiler. Finally, the publisher (8) provides a link to the generated application so that students can install it on their mobile devices.

[2] https://www.imsglobal.org/learningdesign/ldv1p0/ imsld_infov1p0.html
[3] https://cordova.apache.org/

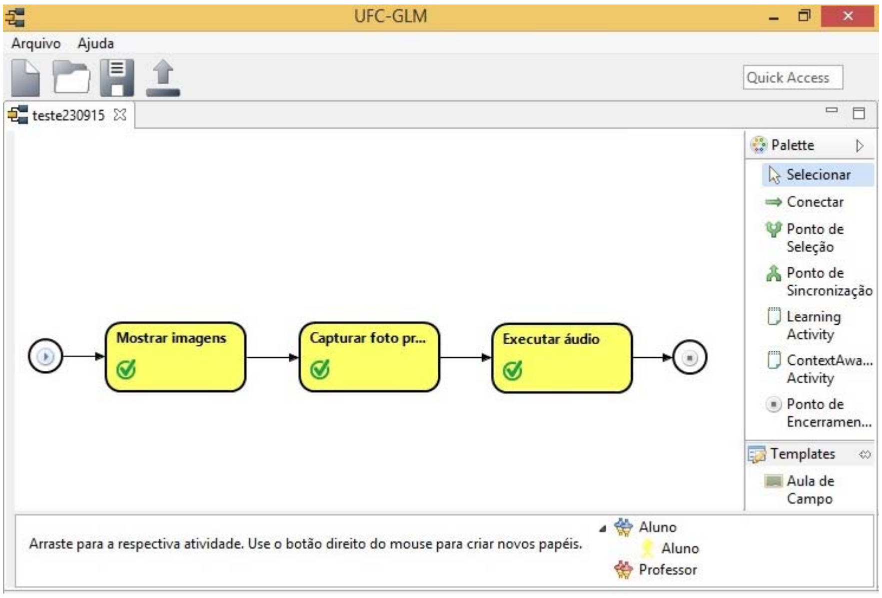

Figure 4: The main screen of the UFC-GLM module. It shows a model with three actions: show images, capture a photo, and play audio

4 Evaluation

We implemented the research evaluation with two groups. The first group was composed of five teachers who work with field trips. The second group was composed of seventeen undergraduate students during a field trip of Geology. The evaluation goal with the first group was to assess the UFC-Inventor usability by its target audience. Our objective was to understand the acceptance of this kind of technology and to confirm that field trip teachers can use them properly. The second evaluation was a case study in which undergraduate students have used a ubiquitous application generated by their Geology teacher using UFC-Inventor. We aimed to gather initial evidence that teachers and professor are able to use UFC-Inventor in real field trips.

4.1 Assessment with field trip teachers

In this assessment, we verified the overall usability of UFC-Inventor. We checked teachers can model ubiquitous field trips with UFC-Inventor. Additionally, the teachers were invited to generate ubiquitous applications with the tool.

4.1.1. Procedure

The usability evaluation sections of the UFC-Inventor had four steps (Figure 5). Initially, teachers were interviewed to identify their profiles. Then, the teachers participated in a short training, in which a researcher showed the UFC-Inventor features. After acquiring knowledge about the approach, participants had to perform three tasks using the environment:

i. modelling a ubiquitous field trip with image and audio resources;
ii. building an application from the model of the previous task; and finally;
iii. participants had to model a more complicated field trip (with text, image, audio, image capture), and generate the correspondent ubiquitous application by using the UFC-generator. Finally, participants answered a usability evaluation questionnaire.

4.1.2. Sample

Five teachers, aged between 35 and 49 years, who teach in disciplines that usually perform field trips had evaluated UFC-Inventor. One teaches a Geology course at the Federal University of Ceará in Brazil; another is a Zootechny professor at the same University; and, the last three participants are elementary school teachers, two of Geography, and one of Biology. They all had practice with the use of software, such as text editors. Regarding their classroom experience, it ranged between six and fifteen years.

4.1.3 Instruments

For this evaluation, we designed a questionnaire with two parts (listed in Appendix A): the first one follows the System Usability Scale - SUS [Brooke, 96]. To measure the degree of agreement, we used a Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The second part of the instrument was composed of one open-ended question, in which teachers could point out suggestions, positive aspects, and negative points of the approach.

4.1.4 Results

The first positive result is that all five participants were able to perform the three tasks correctly. Figure 5 also summarises the evaluation results and also indicates the time for each activity. The participants completed the three tasks in 29.6 minutes on average. For example, the time to finish the first task varied between 7 and 13 minutes. In the third task, more complex, we notice that the teachers of the University were the fastest. Nevertheless, the standard deviation (SD) of the five participants was not very large (3.4 min).

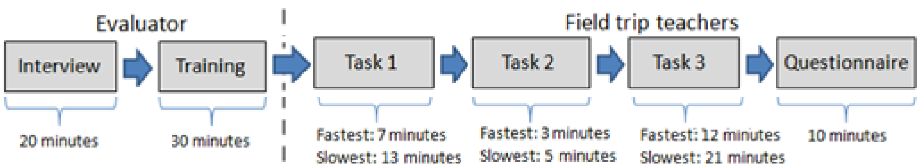

Figure 5: Evaluation of field trip teachers

Table 3 shows the results of the usability questionnaire. Positive results indicate a good acceptance of the UFC-Inventor by teachers. In three items (1, 7 and 9), all participants responded affirmatively ("Agree" or "Strongly Agree"). In general, the average results of the assessments are favourable: average positively worded items equal to 4.16 and average of the written items negatively equal to 1.84.

Regarding the open-ended question, the teachers indicated as positive points: the UFC-Inventor ability to allow the creation of educational applications with various multimedia content; the fact the tool does not require programming knowledge to use it; and, the generation of an ubiquitous cross-platform application.

Teachers indicated two critical points concerning UFC-Inventor. First, the inability to visualise the evolution of the application interface throughout the project. This problem can be minimized by creating partial versions of the application. The second downside was the absence of a detailed tutorial describing step by step how to use the tool functionalities. We intend to include video tutorials in the future versions of the UFC-Inventor.

Question	Mean	SD
1. I think that I would like to use this system frequently.	4.60	0.55
2. I found this system unnecessarily complex.	1.80	0.45
3. I thought this system was easy to use.	4.00	0.71
4. I think that I would need assistance to be able to use this system.	2.40	0.89
5. I found the various functions in this system were well integrated.	3.60	0.55
6. I thought there was too much inconsistency in this system.	2.00	0.71
7. I would imagine that most people would learn to use this system very quickly.	4.40	0.55
8. I found this system very cumbersome/awkward to use.	1.20	0.45
9. I felt very confident using this system.	4.20	0.45
10. I needed to learn a lot of things before I could get going with this system.	1.80	0.45

Table 3: Evaluation results of UFC-Inventor with field trip teachers

4.2 Field Study

According to [Ainsworth, 04], a full analysis of an authoring system requires an observation of both the authoring software and its generated applications. Our evaluation with students considered this aspect and followed the same evaluation scheme done by [Shakil, 11]. The case study had three phases: pre-field phase, in which a teacher has modelled a Geology field trip and created a ubiquitous application with the UFC-Inventor; phase field, in which students used the generated application in a field trip in north-eastern Brazil; and post-field phase, when the teacher could view the information recorded by the students.

The main goal was to evaluate all phases of our approach (from modelling to the use of generated ubiquitous applications) and the usability of the ubiquitous applications with its target audience under real conditions of use. With this in mind, we sought to examine the following questions: Do the transformations between models worked fine (i.e., from high-level representations of field trips to multiplatform ubiquitous applications)? Does the generated application by the UFC-Inventor present good levels of usability, learnability, and usefulness for undergraduate students? Did the teacher approve the adoption of the UFC-Inventor environment as a support tool to the field trips?

This section describes this case study we implemented during a real field trip with seventeen students and their Geology teacher. A video demonstrating the modelling, generation, and use of the case study application is available at https://youtu.be/2NfjMOYQzNY.

4.2.1 Sample and Materials

To conduct the case study has chosen the discipline "Land Mapping Sedimentary" which is part of Geology course at the Federal University of Ceará. The study was conducted in the second half of 2015, in December, in the Araripe Basin region which is in Nova Olinda, in the state of Ceará – Brazil. During the application use the sites of the geological outcrops, we observed that there was no mobile Internet connection and sometimes there was not any cell phone signal.

The selected group was composed of a teacher and seventeen students, aged between 20 and 27 years old. The teacher had participated in another experiment with the use of applications in teaching Geology [Marçal, 14], but had never used an educational application authoring tool. All students had experience with field trips and the use of applications on mobile phones. Only four students had phones that did not support the application. Extra mobile phones were taken to overcome this problem and enable all students to use, individually, devices to perform the tests with the generated application. Fifteen students had Android and two Windows Phone.

4.2.2 Instruments

We used an instrument composed of eighteen questions divided into three parts (listed in Appendix B). The first part, based on the SUS, aims to collect information about the ease of use (Usability) of the generated application and simplicity to learn how to use it (Learnability). The second part, derived from Davis Technology Acceptance Model - TAM [Davis, 89], is intended to identify the application's utility level perceived by students (Perceived Usefulness). Both parts of the questionnaire use the Likert 5-point scale. The third part has two open-ended questions, which aim to collect students' opinions about preferences in the use of application resources, strengths, weaknesses, and improvement suggestions.

4.2.3 Procedure

Figure 7 shows a diagram with all actions performed. It can be seen the case study involved three actors: the evaluator (one of the authors of this paper), the teacher and the students. The process begins with the selection of the group (teacher and students) who will participate in the assessment. The evaluation took place in two locations: at the University, in the pre and post-field performed by the evaluator and the teacher; and in the field, while students were attending a field trip. Before starting the field trip, the evaluator has demonstrated the operation of the generated application. It contained educational content and specific questions about each of the six outcrops, which should be answered by the students in the field. The class lasted from 7 am to 3 pm. Figure 8 shows the students using the application in an outcrop during a field trip. Students listened to the teacher's explanations, held notes in the field notebook and used the application to view content and answer the questions contained therein.

4.2.4 Results

The first important verification obtained through the case study was the finding of the operation of the proposed process by the UFC-Inventor. From the graphical model developed by the teacher was obtained the specification of the field trip in the ML4UL language. Based on it, the source codes were created to be used to generate the executable applications on the target platforms. Specifically, in this case study, we generated three versions of the application: two distinct styles with Android and another for Windows Phone. Figure 6 presents some screens of the application generated for the case study.

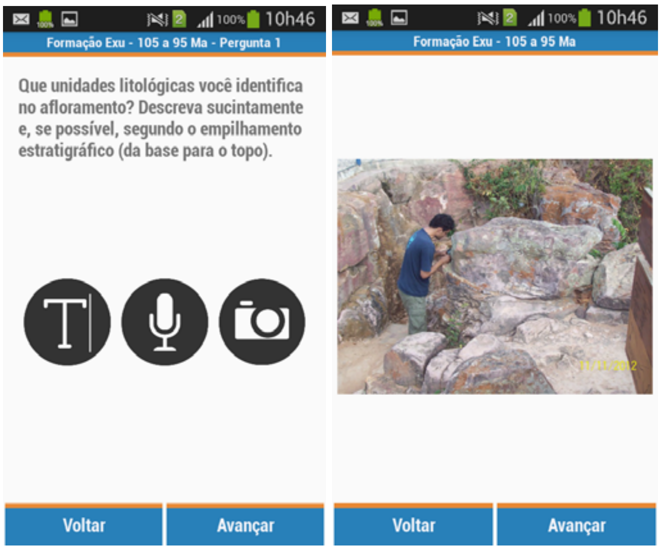

Figure 6: The figure presents some screens of the application generated for the case study. The left screen is a question, which the students can answer via text, audio, or photography. The screen on the right shows an image with examples of rocks from that formation in study

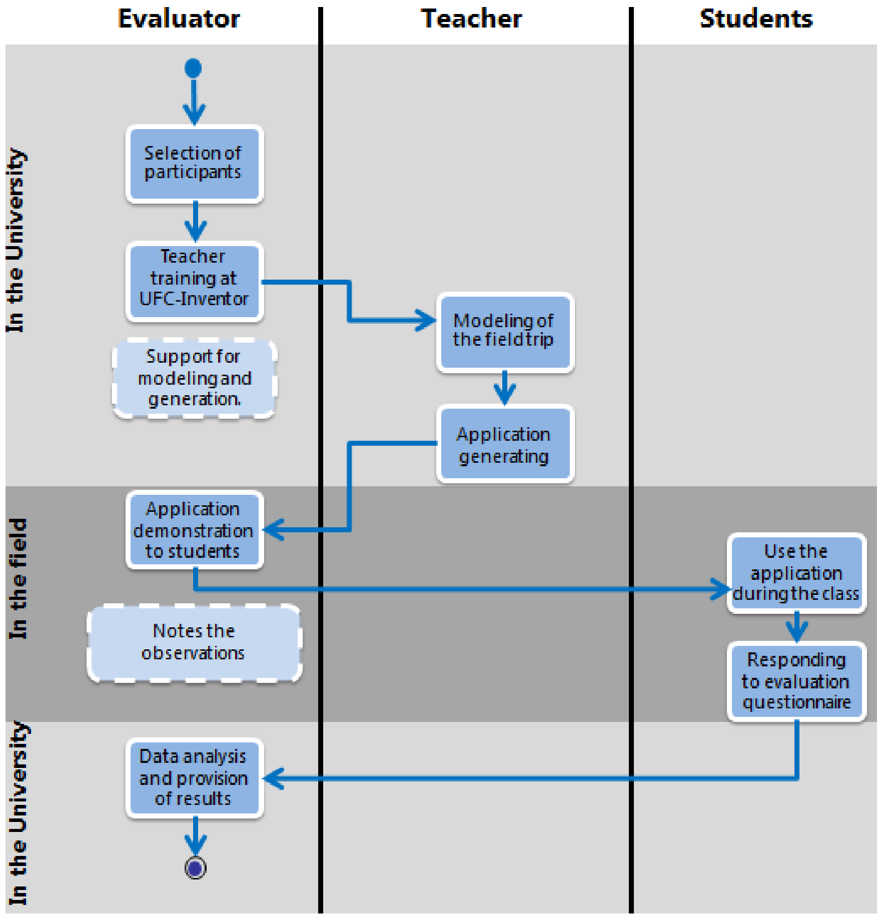

Figure 7: Procedure of the evaluation with students

It is important to highlight that, after working out the model of the field trip, the geology professor could generate versions of the application without the help of programmers. While using the application in the field, the features in the different versions had similar performance, working properly as expected by the teacher. For example, regardless of the operating system or used layout, navigation between screens followed the same sequence and capture features (microphone and camera) work correctly in the three versions.

Figure 8: Students using the application in the field trip

Table 4 summarises the analysis of the responses the first part of the evaluation questionnaire, which corresponds to the items based on the SUS questionnaire. The results demonstrate that the application received a good usability evaluation (mean SUS score of 83.4), considering a minimum SUS score 70 to an acceptable level of usability [Sauro, 11]. It also can say with 95% confidence that the SUS score for this population is between 79.1 and 87.6.

Variable	**Value**
Sample size	17
Mean SUS Score	83.4
Confidence Interval	79.1 – 87.6
Margin of Error	4.2
Confidence Level	95%
Standard deviation	8.2
Cronbach Alpha	0.819

Table 4: Summary of the analysis of the first part of the evaluation with students

To certify the reliability of the data, we used the Cronbach's alpha [Bonett, 15]. Table 4 shows the sample achieved a good level of reliability (Cronbach's alpha equal to 0.819), with 0.70 considered the lower boundary for an acceptable internal reliability [Sauro, 11]. Table 5 shows how the tested application is classified with respect to two different scales. As it can be seen, using the categorization of [Bangor, 09] the generated application ("Field Trip") is classified in category B, which is the usability level "Excellent" that scale. According to the classification of [Sauro, 12], the generated application gets grade A. In both scales, the application ranks the second best usability evaluation level.

SUS Score of the app "Field Trip."	[Bangor, 09]		[Sauro, 12]	
	Range	**Grade of the app "Field Trip."**	**Range**	**Grade of the app "Field Trip."**
83.4	80 – 90	B (Excellent)	80.8 – 84	A

Table 5: Classification of the generated application ("Field Trip") according to two different scales

Figure 9 shows a box plot graph that provides an analysis of the distribution and symmetry of the results obtained from the answers of students based on the SUS scale. We can observe in this figure an approximate distribution of the characteristics results (mean score SUS, Usability and Learnability) around 80. The second part of the questionnaire given to the students was based on Davis's TAM, which unlike the SUS, has no standard formula to derive a single average result and make findings on it. We did the data analysis by comparing the average values for each item [Zbick, 15; Myers, 14; Park, 14; Weng, 14]. Table 6 shows the average values of the answers of the second part of the questionnaire, regarding the evaluation of usefulness perceived by students about the application.

Item – The application…	Mean	SD
11. Facilitated me to collect data using features such as camera and microphone.	4.47	0.51
12. Difficult me to write text and numbers.	1.82	0.53
13. Allowed me to perform the tasks in the field more efficiently.	4.12	0.60
14. Complicated the execution of my learning activities.	2.00	0.71
15. Is a useful technology for data collection.	4.53	0.51
16. Helped me to better understand the concepts of field trip.	3.94	0.75

Table 6: Student responses to the second part of the evaluation questionnaire

The average value of written items positively (11, 13, 15 and 16) was 4.26. Of these, only one item (16) obtained grade below 4.0 (equivalent in Likert scale 5-point the "I agree"), yet with a value close to (3.94). With respect to items written negatively (24 and 14), the results show that the students disagree that the application impedes their use and complicate the execution of learning activities (lower average or equal to 2.0). From the answers of the students, it can be observed the good acceptance of the application tested in the field. Items 11 and 15 stand out positively, once all seventeen students said they agree or strongly agree that the application is a useful technology for data collection and facilitates this task through the use of the camera and the mobile microphone. Another highlight is item 13, which the majority of students (88.2%) agree that the application allowed the field tasks were performed more efficiently.

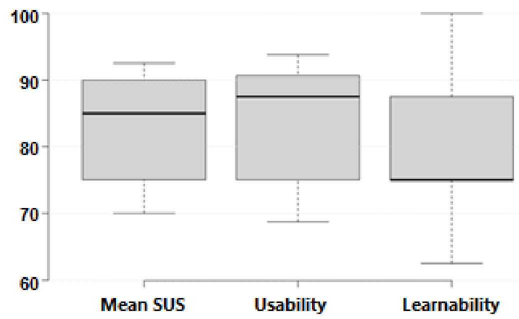

Figure 9: Box Plot of Mean SUS, Usability and Learnability

In the third part of the questionnaire, the students had the opportunity to write comments on the application. In question 17, they should answer about what form (via text, photo or audio) preferred to use the mobile device to answer the questions on the application. From reading the responses, we concluded that the text input (via touch screen) was preferred because of convenience and the user's custom of using this form of interaction with the device. On the other hand, the audio recording (via microphone) is the least used option since it is not an unusual feature to answer exercises. In the last question, students should list the positive and negative aspects of the application use. Users indicated as positive points: the facility to collect data in the field during class; the fact of being one more way to store the field trip information; the content of the application helped to understand the concepts taught by the teacher; the importance of being able to store the data in different forms (text, audio and photo); the ability to record the geo-located data (via GPS); and practicality to collect the information.

Regarding weaknesses and suggestions for improvements, the main complaint of the students was the fact that the application only allows capturing one photo by a question and by outcrops. Some students also said that the application could display graphics and useful tables for the field trip. Other suggestions: change in the order of content presentation (text and images) and capture of information; and display of outcrop coordinates, which the app stored it, but it‘s not showed to the student.

To demonstrate the benefits of adopting the UFC-Inventor environment in the post-field phase, we use the Google Fusion Tables database. For this, a Web system was designed to access and view the data recorded on the field trip (Figure 10). It can be seen on the map markers indicating the six outcrops visited. Figure 10 also shows a balloon with the basic information (in the centre) and the answers (in the text, audio and image) to the questions about the selected outcrops (left side of the figure). About the case study, the geology professor claimed to have had no difficulty in using the authoring tool to design the ubiquitous field class. He highlighted the fact that the diagram style is similar to traditional flowcharts, which facilitated his learning. He also emphasised the simplicity to add resources such as images and the GPS sensor. He said that the generated application reflected the elaborate design and was within the expected.

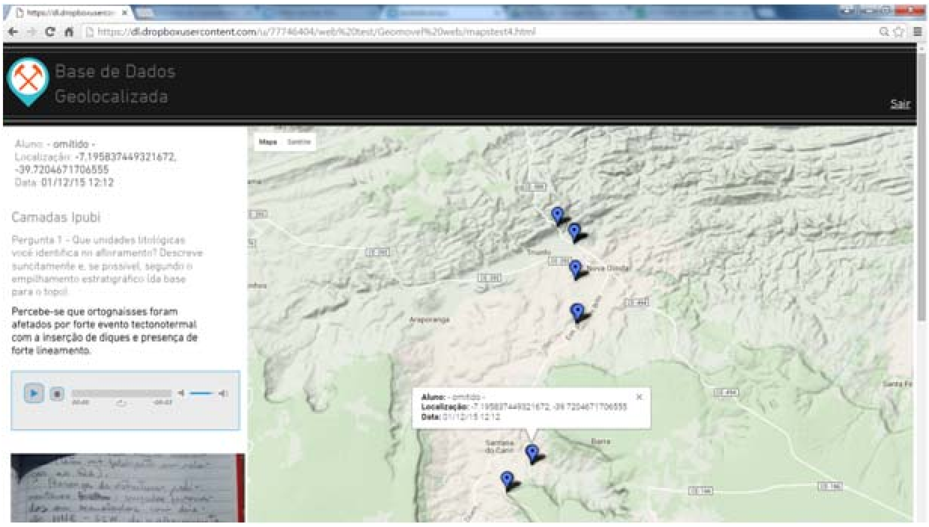

Figure 10: Visualization of data collected in the field

On the use of the application in the field, he noted that all the students were using the application. He also realised that they took each other questions about the use of the application and did not ask for his help. After returning from the trip, he accessed the Web system shown in the previous section. He highlighted both the information provided by the system and the choice of Google Fusion Tables platform, being a platform already used in geology studies. Finally, the professor concluded stating he was excited with the results of the experiment and hoped to use the environment in field trips in others disciplines and geographical regions.

5 Discussion

This paper goal was to present the development and the evaluation of a system aimed at supporting the use of mobile and ubiquitous technologies in field trips.

It is important to note that when compared to the related works (Section 2.3, [Giemza, 11; Tabuenca, 14; García, 14; Xie, 15]), UFC-Inventor is the only one capable of generating applications with ubiquitous computing resources for distinct operating systems. UFC-Inventor does that with a graphical modelling interface, which does not demand computer programming skills. Also, we outstand two other UFC-Inventor features: i) the use of an open specification (ML4UL), which enables interoperability with other tools; and, ii) the independence of Internet connection in the applications generated. This feature was essential to the success of the case study, given that at many times there was no Internet connection during the field trip.

By testing with teachers, we found UFC-Inventor has a good level of usability. Furthermore, all teachers have been able to model and generate ubiquitous applications (however, there were differences in the time to perform these tasks). This result is important because the participants in this evaluation are education professionals with no programming skills, which are the main target group of UFC-Inventor (response to RQ1).

From the case study, we observe that UFC-Inventor allow the modelling and the generation of an effective application, which was used and approved by students in a real field trip. The data analysis showed that the generated application achieved good levels of usability, learnability, and perceived usefulness by the students (response to RQ2). Also, the data collected in the field were relevant to a post-field analysis, as evidenced by the teacher who participated in the case study that showed interest in continuing using the environment in their field trips.

Some drawbacks were pointed out by the students. They are more related to content issues, such as the need of better teaching material or changes in the presentation format. These adjustments can be made with changes in the class model by the teacher himself, without implying changes in UFC-Inventor tool. We believe that the more the teacher use UFC-Inventor, the more he/she will perceive the most appropriate amount of content and tasks to place in the application.

We also had some implementation issues stemming from Cordova platform limitations. Initially, we imagine that with the model in ML4UL, the tool could generate a single source code (in Javascript). However, variations in the implementation of the Cordova platform in the three mobile operating systems prevented this. Thus, the development team had to specify these variations for each platform in the transformation rules.

In addition to the source code itself, we found that operating systems required specific versions of style sheets (CSS files). During the programming tests, from the application of the case study, it was possible to observe differences and faults in the layout. For example, the same interface that worked well on Android had scrolling problem, and the components disappeared in Windows Phone. Therefore, we created specific CSS files for each operating system.

6 Conclusion

The UFC-Inventor environment has proved to be an interesting solution to enable professionals without programming knowledge to design field trips with mobile and ubiquitous computing resources. Thus, we believed UFC-Inventor could become an important tool to promote the use of these technologies in education. The test results with teachers and students of geology corroborate this expectation.

Regarding the limitations of this research, it is important to say that we did not evaluate learning gains from the use of the generated application. This question was out of the scope of our research and evaluation, which was more focused on demonstrating the full operation of the UFC-Inventor environment.

However, this is an important issue that we should investigate in future works. Furthermore, it is important that new experiments in other educational areas are carried out to demonstrate other benefits provided by the UFC-Inventor. However, to implement these new evaluations, we need teachers who are willing to adopt these technologies in their classrooms.

Other future works are more related to the technical aspects of UFC-Inventor. For instance, we want to incorporate some Internet of Things technologies; improve the process for integrating external tools; develop and experiment new interface layouts, compatible with other mobile devices (e.g., smartwatches); and, finally, to migrate the modelling tool to a collaborative Web platform.

Acknowledgment

We would like to thanks CNPq (http://www.cnpq.br/) for supporting Rossana Andrade, one of the authors, with a productivity research grant (DT-2).

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APPENDIX A

Teacher Evaluation Questionnaire - UFC-Inventor

Objective: UFC Inventor Usability Evaluation
Methods: SUS - System Usability Scale, Open Questions

PART I – About the UFC-Inventor, score the following ten sentences with one of the five responses.

1) I think that I would like to use this system frequently.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

2) I found the system unnecessarily complex.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

3) I thought the system was easy to use.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

4) I think that I would need the support of a technical person to be able to use this system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

5) I found the various functions in this system were well integrated.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

6) I thought there was too much inconsistency in this system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

7) I would imagine that most people would learn to use this system very quickly.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

8) I found the system very cumbersome to use.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

9) I felt very confident using the system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

10) I needed to learn a lot of things before I could get going with this system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

PART II – Open-ended question

11) Highlight the good aspects, issues, and your suggestions about UFC-Inventor.

APPENDIX B

Student Evaluation Questionnaire - UFC-Inventor

Objective: Mobile Application Evaluation
Methods: System Usability Scale (SUS), Technology Acceptance Model (TAM), and Open-ended questions

PART I – About the mobile application you used in the field trip, score the following ten sentences with one of the five responses.

1) I think that I would like to use this system frequently.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

2) I found the system unnecessarily complex.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

3) I thought the system was easy to use.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

4) I think that I would need the support of a technical person to be able to use this system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

5) I found the various functions in this system were well integrated.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

6) I thought there was too much inconsistency in this system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

7) I would imagine that most people would learn to use this system very quickly.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

8) I found the system very cumbersome to use.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

9) I felt very confident using the system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

10) I needed to learn a lot of things before I could get going with this system.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

PART II – Concerning the mobile application features:

11) The mobile application allowed data collection quickly, by using its features such as the camera and the microphone.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

12) The mobile application makes hard to write text and numbers.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

13) The mobile application made the execution of my field trip activities more efficiently.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

14) The mobile application complicated the execution of my learning tasks.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

15) The mobile application is a useful technology for data collection in the field trips.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

16) The mobile application helped me to understand the concepts of the field trip better.

() Strongly Disagree () Disagree () Indifferent () Agree () Strongly Agree

PART III – Open-ended questions

17) How did you prefer to answer the questions in the application?

( )Text ( ) Audio ( ) Photo. Why?

18) Highlight the good aspects, issues, and your suggestions about the mobile application.