Design of Adaptive Micro-Content in Second Language Acquisition

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Keywords: adaptive systems, micro Learning Object, device-adapted content, ontology-based reasoning, CALL (computer-assisted language learning)

Content adaptation with respect to different devices technical constrains is often a necessary step to make content usable. Moreover, in the field of Language Learning, content adaptation to different devices involves rather peculiar issues, if compared to other domains. Every teaching module is made up of different interconnected components: the educational technique, the abilities and competences it aims to develop and the activity type implementing the technique. It must however be kept in mind that adaptation may involve changes in terms of format, mode or type of activity which can result in alterations as regards the abilities the content was originally developed for. In this paper we deal with these issues and introduce our approach to address them, in particular as regards content to be delivered through the CLiRe online language learning environment. Our approach consists in the design of micro-content that can be processed by an ontology representing the above mentioned relationships and by means of reasoning

for citations:
Mercurio M., Torre I., Torsani S. (2011), *Design of Adaptive Micro-Content in Second Language Acquisition,* Journal of e-Learning and Knowledge Society, English Edition, v.7, n.3, 109-119. ISSN: 1826-6223, e-ISSN:1971-8829

mechanisms capable of deciding which changes need to be done to adapt a given content to a specific device.

1 Introduction

Designing multi channel learning content means both to adapt formats and content to the device's and the channel's constrains and to exploit the possibilities the devices actually provide. The obvious advantage of multi channel design is that the learner's different devices can be exploited so that content can be accessed throughout the whole day: this model of pervasive e-learning is developed after the philosophy of *microlearning* (Lindner, 2007). Such a design, however, requires the resources are able to adapt themselves to the device's features so as to make fruition as satisfactory as possible.

Resources contained in e-learning environments are usually not accessible through mobile devices: this is not surprising given the differences in terms of operating system and format among the different devices (Arai & Tolle, 2011). It becomes thus necessary to design adaptive systems capable of facilitating the learning experience no matter the device: according to research, low usability can actually compromise learning effectiveness (see Meiselwitz & Sadera, 2008).

In the field of *Language Learning*, content adaptation becomes particularly tricky as any alteration in terms of mode and type involves not only technical matters, but can affect the content itself and, as a consequence, the abilities the learner needs to acquire. Mode conversion (e.g. text vs. audio) is not a neutral operation, as oral and written comprehension are two different abilities. Similarly, exercise type adaptation, e.g. cloze test vs. multiple choice (the latter being more usable on mobile devices) is often not a neutral conversion as regards educational effectiveness.

This paper is centered on these topics and introduces our approach to multi channel resource design for a PET (Cambridge Preliminary English Test) certification course, to be implemented on the CLiRe Language Learning Environment (Torsani, 2011).

Our approach consists in the development of a knowledge base containing both the relationships among techniques, abilities and types of exercise and the devices' features as regards usability problems that may arise with certain activities. By developing this knowledge in an ontology we are able to evaluate the resources' fitness with regard to the device and the necessity of transforming them.

As we will see, to formalise these relationships is a quite hard operation both because of the complexity of the relationships themselves and because of the lack of solid and shared research findings on the effectiveness of language activities for specific abilities. Present-day CALL research is in fact mainly focused on socio-cultural approaches (based on the results of participants interaction) rather than on more traditional activities, like language exercises, be they delivered through personal computer or mobile device. Research on language exercises, on the other hand, has not yet produced a shared view on the matter, on the contrary: the discrepancies between the two famous studies on exercises - that of VanPatten and Cadierno (1993) and that of DeKeyser and Sokalski (1996) - are quite representative of this fact.

If we are to adapt resources and make them usable through different devices, we will have to deal with these issues and to formalise the relationships among the involved entities. In this paper we will try to understand if and how a given activity form can actually foster a certain ability: oral comprehension, written comprehension, oral production, written production, grammar and vocabulary. These six domains have been chosen as they are part of the curriculum for the PET exam and are described in specialised literature (De Mauro, 1998) as well as in manuals (Capel & Nixon, 2003).

2 Objectives and framing of the project

OBJECTIVE: *We want to manage each mirco-content so as to maximize its usability with regard to the device and to reduce as much as possible any loss or alteration of its effectiveness with regard to the linguistic ability it was designed for. Should a transformation result in an excess of effectiveness loss (computed through numeric values), it should have to be compensated.*

As previously said, a low usability of the Micro Learning Object (mLO) can result in a low effectiveness of learning by reducing the learner's motivation and raising her/his cognitive load: the learner's effort must be directed towards the acquisition of content and not towards the use of the device.

In order to comply with the above mentioned objective, it is necessary to define some evaluation functions to make the system determine:

1. the mLO's format and type fitness with regard to the device
2. how to transform the mLO so as to make it fit for the device
3. how to compensate any eventual effectiveness loss (caused by activity' a transformation of the mLO).

The mLO is an object designed to be used on a personal computer and transformed when its usability on a given device is too low.

DEFINITION OF MLO. In order to make a mLO subject to evaluation and transformation we need to make it a discrete element within the platform it is embedded in: in other words we need a formal definition of the mLO.

In our model, a mLO:

- aims at developing one ability (among those introduced in §1),
- makes use of a specific educational technique, as defined in specialized literature (see Balboni, 1995; 2002),
- is a structured set of discrete elements - which we define as Components (C) –which can be either an Input (I) element - for instance a reading text or an audio track – or an Activity (A) related to I.

The structure of a mLO can be formalized as follows:

```
mLO = ((I, mode)+, (A, type, mode)*)
```

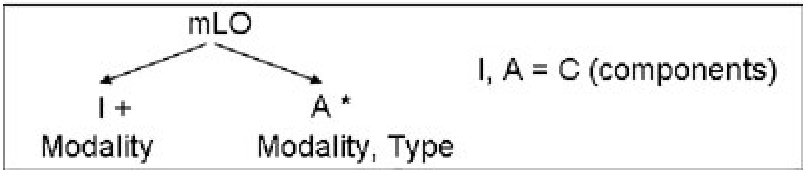

Fig. 1 – A mLO structure

- I= input = {reading text, audio track or video, etc.}
- A = activity that, combined with I, implements the technique of the mLO = {image/language match, selective leistening, etc.} The cardinality of the components is expressed by means of regular expression metacharacters (+, meaning "one or more of a given item", and *, meaning "zero or more of a given item") Every component is defined in terms of modality and format (i.e. audio/mp3, image/jpg, text/html etc.) Activities (A) can be developed through different exercise forms. We will adopt Heift's terminology (2003) and will call a *Type* each different form of exercise
- A(*Type*) = the different forms an Activity can assume = {match, multiple choice, cloze test, etc.}-

DEVICE FEATURES A MLO MUST FIT TO BE USABLE

Several organizations are engaged in defining the features of the devices. We chose to use the device descriptors stored in the well known WURFL repository.

TABLE 1
WURFL Hd/Sw features that can influence mLO usability

Device Features	Values	Peculiarities of the mLO (I/A components) influenced by the device features
Keyboard	Querty Keypad, PhoneKeypad, Querty Virtual	The activity requires text
Pointing device	clickweel/trackball, joystick, stylus, touchscreen, etc.	The activity requires frequent interaction
Build_in_recorder	yes/no	The activity requires audio recording facility
Display size	Pixel based (ranges)	The component needs to be entirely displayed on the screen (for images)
max_image_width, height	Pixel based (ranges)	The activity requires audiovideo reproduction facility
Audio/video playback	yes/no	The activity requires audiovideo reproduction facility
Streaming	yes/no	The component requires streaming

It is based on the UAProf profiles, revised and updated by the developers community. In Table 1 we report the set of features we take into account for our mLO adaptation. This list does not include features that concern audio/video format supported by devices.

3 MLO adaptation

Given a specific mLO (defined both in terms of its *components* and of the *ability* it aims at developing through a specific technique) and given a specific device (defined in terms of the features in Table 1), we have faced the issues specified in §2 as follows:

1. through the use of an ontological representation to define all the entities involved in the adaptation,
2. by coding through values the relationships among the different entities,
3. by defining a set of rules for the assessment and transformation of mLOs.

3.1 Transformation ontology

As shown in Table 1, our ontology is made up of a set of classes representing the mLO and its features (§2): `<mLO>`, `<ability>`, `<component>`, `<technique>` with the last one, `<developedAbility>`, being a reification (i.e. transformation into object) of the relationship *developedAbility* that represents the value of the relationship between a specific component and the ability.

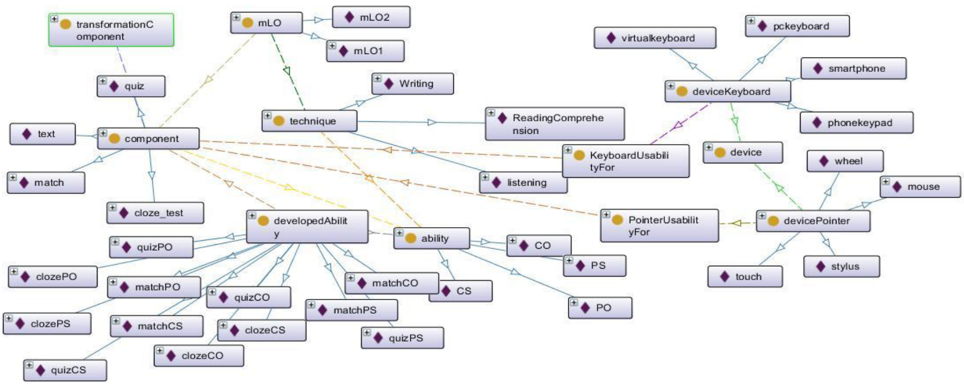

Fig. 2 – Part of the transformation ontology

A second set of classes describes the device `<device>` and its features. To determine a component's usability (for instance, a quiz, a cloze test etc.) with respect to the device's features, we need to define a relationship between these entities. As with the relationship between component and ability, we use reification to describe the relationship between device features and usability (e.g. `<PointerUsabilityFor>`, `<KeyboardUsabilityFor>`, etc.). Each class describes the usability of a certain device feature with respect to a certain component).

3.2 Relationships instantiation

Once the ontology is defined, the next step is to assign a numeric value to each relationship in order to use it to transform our mLO. In particular, considering the two relationships mentioned above, we have to assign values to (i) `<developedAbility>`, which defines the suitability of the mLO *components* to develop a specific linguistic ability, (ii) `<PointerUsabilityFor>`, `<KeyboardUsabilityFor>`, which define the usability of the components, given a specific device feature.

As discussed in §1, to determine whether an activity is suited for the development of a certain ability is not an easy matter, nor is there agreement among researchers: the values we assign to each relationship are therefore approximate and should be empirically rectified.

Approximate as they may be, however, our evaluations are based on a number of studies we will briefly introduce. We will focus on the *components* which constitute the Activities (A). Activities, as we said in §2, can be of different *Type*: in our environment we take into account six different *Types* (quiz, match, "closed" cloze test, "open" cloze test, sentence recostruction and free sentence). From different studies that have dealt with the analysis of these *Types* of Activity, we chose some features we have found useful for the development of our model of ontology, namely *task*, *frequency* and *range* (§Table 2).

TABLE 2
Types of activities classified with respect to Task, Frequency e Range

Type	Task	Frequency	Range
Quiz	Click	1 ≤ freq < n (1= one choice, n choices)	<=n possible answers
Match	Drag and drop	N	=n possible associations
Cloze test	Clik + insert (short)	n (=blank spaces)	∞ (infinite answers)
Cloze test (closed)	Click+insert (short)	n (=blank spaces)	=n possible answers
Reconstruction	Click+insert (long)	n (number of words in the sentence)	n! (factorial on the number of words)
Free sentence	Click+insert (long)	∞ (infinite)	∞ (infinite possible answers)

These features are very important, as it is through them that researchers have defined the relationships we want to formalize (§Table 3). Table 2 and 3 must be considered jointly: Table 2 provides the Activity Types and their features, while Table 3 provides the relationship between these features and (i) the abilities whose development they should foster and (ii) the device's features that determine an Activity's usability with regard to the device. By combining the values of the two tables, we define the relationships connecting Activity *Types* with (i) ability development and (ii) usability for a given device.

Let us consider now these activity features in detail. *Task*, that is the kind of interaction an activity requires (e.g. clicking, dragging and dropping, entering text etc.), was discussed by Heft (2003) and is strongly connected with the device's features (e.g. the kind of keyboard etc.), while weakly connected to the developed abilities (§Table 3).

Frequency and *range* were researched by Laurel (1991). With *frequency* she indicated the number of times a learner must interact with the activity, while *range* represents the number of options available for the resolution of each single point. For instance, in the *quiz* activity the *task* is represented by the act of clicking, the frequency by the number of questions to be answered (1 to n), while the number of possible answers represents the range.

For the definition of Table 3 we have relied on the conclusion of both Nagata (1998) and Heift (2003). Both researchers have shown that learners who had practised on output-based activities (production exercises with high frequency and especially range values) performed better than those who had practised on input based activities in which frequency and range are comparatively smaller. This study shows a possible relationship between such factors and production abilities. On the connection between exercise types and comprehension abilities evidences are scarce and we will therefore consider the activity types as being neutral in this respect.

TABLE 3
Impact of different activity features on usability and linguistic abilities

Activity feature	Value	(i) Influence on the lingusitic ability	(ii) Device's features influencing usability
Task	Click		Pointing method
	Click + insert (short)		Pointing method and kind of keyboard
	Click + insert (long)	Light impact on the ability	Pointing method and kind of keyboard (important)
	Drag and drop	Light impact on the ability	Javascript/flash support and pointing method
Range	from 1 to ∞	> range -->impact on the ability	
Freq	From 1 to ∞	> freq --> impact on the ability	Pointing method

So far, we have described but a few relationships in our ontology. Another important relationship is that between the ability and the techniques we implement in our mLO. On this point there exists a much larger literature (see Balboni, 2002) that allows clearer relationships such as that between "selective listening" or "language and image match" (activity) and "oral comprehension" (ability).

3.3 MLO Assessment and transformation rules

Once our ontology is structured, we can now put into practice the three reasoning mechanisms introduced in §2 by defining some new relationships between the ontology classes and a *set of rules* we have developed through SWRL (Semantic Web Rule Language).

1. *assessment of the fitness of the mLO (type and format) with respect to the device in use:*

we need to set a new relationship *suited_for_device*, defining the fitness of each component with respect to the device: the rule produces a fitness value.

2. *assessment of the mLO format transformation with respect to the device in use*

these rules are triggered only if the previous inference produces a result below a given threshold;

- this reasoning evaluates the transformation utility in that it compares solutions with a *high usability value as regards the device but with reduced utility as regards ability learning vs. solutions with lower utility as regards usability but with average/high utility as regards ability learning*
- this evaluation requires also the definition of a new relationship, reificated in the `<transformationComponent>` class that defines the technical transformability of each component type with that of the other.

3. *Assessment of activity compensation in case of content loss (abilities) resulting from a mLO transformation:*

these rules apply if the preceding ones have determined that it is more useful to transform a mLO into one whose usability is high but with a significant loss in terms of ability development. In this case it is necessary to compensate this loss by adding other activities to the transformed mLO or later on.

3.4 Case study of transformation

Let us consider a mLO whose aim is to develop the "oral comprehension" ability and which is composed, as to the scheme in §2, of an audio track (I) and a cloze test (A). The track is about a family and the exercise is a mask in which the learner must enter the names of the members of the family presented in the passage (e.g.: father_________). If we were to use this mLO on a mobile phone, the reasoner would have to determine its usability with regard to the device of each of the mLO components: it would also have to determine if the device supports audio playback (§ Table 1 – audio/video playback) and if the device keyboard is suited for the cloze test as of the rules in §3.3.

1. The first set of rules is activated and the reasoner determines if cloze test is *suited_for the device*. Cloze usability is determined on the basis of the devi-

ce's keyboard and pointing method usability, respectively <Keyboard_usability_for> and <Pointer_usability_for>. As cloze test requires a "click+insert" *task* and a "n blank spaces to be filled in" *frequency*, keyboard and pointing device influence the mLO's usability (§ Table 3). For instance, if the mobile device has a PhoneKeyPad, the usability in this case would be minimal.

2. If, as in the case just mentioned, the value of the *suited_for* relationship is inferior to a certain threshold, a second set of rules is used to assess the mLO transformation. This is done by calculating:

- the usability value of each component
- each component's fitness with regard to the ability to be developed through the mLO technique.

In our example the *quiz* would be the fittest activity type, since it has low range and a simpler task (clicking) if compared with that of the *cloze test* (§Table 2).

Had our objective been to develop a production ability, such a transformation would result, according to Nagata (1998) and Heift (2003), §3.2, in a loss of effectiveness that would have to be compensated. But, as in our example the mLO had to develop oral comprehension, the transformation can be carried out without any further compensation.

Conclusion

In this paper we have dealt with the adaptation of a language learning content for different devices. This adaptation is carried out through a set of rules assessing, on the basis of an ontology, the micro-content's fitness with regard to the device, the transformation effectiveness with regard to the ability to be developed and the compensations to be carried out in case of effectiveness loss as regard the ability to be developed.

As with every knowledge-based system, our approach requires a quite long work as regard the encoding of the field's knowledge with the risk of not having valid research in the field of language (which requires a deep perusal) teaching on which we can base our study.

It must anyway be kept in mind that formalizing knowledge from studies and research loses complexity if we keep at a high level: for instance, by defining the relationships between exercise type and usability with regard to the device's features we might neglect small differences that might be perceived by the user, focusing, instead on more significant differences, near managing accessibility matters instead of usability ones.

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