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Abstract

Purpose – E-learning is part of instructional design and has opened a whole world of new possibilities in terms of learning and teaching. The purpose of this paper is to develop an adaptive e-learning platform that enhances skills from primary school to university learners. Two purposes converge here: a pedagogical one – offering new possibilities, especially in terms of teaching scenarios (blended learning); and a research one – confirming the effectiveness of an adaptive e-learning tool in the case of individualized cross-disciplinary competences, such as comprehension of implicit information in written texts (French).

Design/methodology/approach – The case study presented here concerns primary-school learners using the Implicit module of TACIT adaptive e-learning tool over the 2016-2017 academic year.

Findings – This paper gives a first positive answer to the effectiveness of such a tool in this specific context. This pedagogical effectiveness is more pronounced for low-level pupils, especially for girls and for older pupils (CM1/CM2, respectively, fourth/fifth grade).

Originality/value – In this case study, the module comes from an existing platform, created by the TACIT research group. The adaptive environment was created by using the Item Response Theory models and, more precisely, the Rasch model.

Keywords Rasch model, Blended learning, Adaptive environment, E-Learning Tools, Item response theory, Reading comprehension

Paper type Research paper

1. Introduction

With the rapid development and diffusion of the internet and its related technologies, physical transformations in the classrooms have occurred, alongside changes in the ways of teaching and learning. Being able to search for information on the internet or being able to search for a word in a dictionary are both valid tasks today from a pedagogical point of view. E-learning is

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part of instructional design as Merrill *et al.* (1966, p. 2) defined it: "*a technology for the development of learning experiences and environments which promote the acquisition of specific knowledge and skill by students*". And it became part of a pragmatic research question: can it be a supportive environment which helps in solving a teaching/learning problematic: individualization? Every teacher faces the problem of heterogeneity in the classroom: personalizing the learning process – that is, taking into account individual competences – is time-consuming and difficult to realize when dealing with tight-scheduled programs.

There is a large amount of studies investigating individualized systems and proving their superiority in terms of learners' performance compared to traditional teaching systems or "*one-size-fits-all*" approaches (Vandewaetere *et al.*, 2011, p. 119). Those individualized systems have different forms: student guides, tests, personal corrective feedback, tutoring, etc. But the most basic idea is that it is difficult to create personalized training: it is time-consuming, it is also more demanding in terms of staff and, thus, in terms of budget as well.

However, the reason researchers kept investigating this area is the effectiveness of individualized systems of training. Bloom (1984) identified what he called the "*2 sigma problem*": "*The most striking of the findings is that under the best learning conditions we can devise (tutoring), the average student is 2 sigma above the average control student taught under conventional group methods of instruction*" (p. 4). From there, researchers investigated other parameters influencing learning conditions – parameters different from the teacher – learner relationship: influence and role of peers, tools (complementary computer learning courses, for example). The aim was to reduce the cost of tutoring while attaining the same results.

Slowly, e-learning imposed itself as a solution and was found particularly fitting to put in place adaptive teaching individualized approaches. Bangert *et al.* (1983) showed that "*computer-supported instruction at the secondary level*" was particularly effective, as it kept "*youngsters interested and actively responding while guiding them easily from one level of difficulty to another. The result* [appeared] *to be better learning*" (p. 153). What this study does not highlight is the reason of the effectiveness of computer-supported learning. One of the advantages of tutoring is that it insures a one-to-one configuration (one tutor–one learner) and a consequence of that is the possibility to adapt the pace of the teaching process to the pace of the learner. It is the same for adaptive learning environments: the idea is to match with the pace and level of competence of the learner, giving them the possibility to follow courses at an accelerated or extended pace.

What is exactly adaptive e-learning? Paramythis and Loidl-Reisinger (2004, p. 182) consider a learning environment adaptive:

> [. . .] if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process.

Hence, according to them, one of the first aspects of adaptive learning is *monitoring*. Adaptive means being able to perform this task and so, to estimate the competences of the learners and influence their learning strategies to enhance their performance. Putting in place an external monitoring environment is necessary as learners tend to overestimate their competences when monitoring themselves (Koriat and Bjork, 2005).

When dealing with adaptive environments, as they fit the individualization principles, which have mainly been proved to be effective in terms of learning, there is no real thought given to the learning content available to the learners. Here, our project, which was first

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launched in 2012, tackles the following question: To what extent is adaptive e-learning effective when considering precise – but cross-disciplinary – competences such as comprehension, vocabulary or grammar? This article is a first step to answer this question. First, a state of the project is presented, while questioning the relationship of adaptive and online environments. Second, through a case study concerning comprehension, we try to elucidate the question of the effectiveness of an adaptive e-learning tool when targeting a cross-disciplinary competence. In closing, we present some further developments and possible directions that can be addressed while training learners to develop a particular competence through an adaptive e-learning environment.

1.1 Creating an adaptive online environment

What is exactly e-learning? According to Plantec (2002):

> E-learning simply means using ICT for the various tasks associated to education or training: advertising, administrative registering, document production, synchronous or asynchronous communication between teacher and learner, assessment. This leads to renewed pedagogical approaches which are possibly independent in time and location and to tailor-made programs involving networks of institutions or companies.

As this definition shows, e-learning is a vast domain of varied pedagogical practice and tools existing in both teaching and research fields. But, in recent years, one of the e-learning branches which has heightened a renewed interest in both pedagogical practices' and research interests' sides has been adaptive e-learning. As we underlined a few lines earlier, e-learning has drawn the interest of both teachers and researchers because of the possibilities it offers in terms of individualization.

At the beginning of the twenty-first century, a lot was written and done about online environments. However, not so much was done to create tools which would be entirely adaptable to individuals and which would, at the same time, allow teachers to put in place blended learning, especially in France. Indeed, the idea, regarding this project, is not to replace the teacher–learner relationship by a machine–learner interaction; we want to enhance the possibilities given to teachers to individualize their programs through adaptive e-learning.

In 2001, Coomey and Stephenson (2001) highlighted the fact that, though online activities were more and more used in the classroom, they had not found, at the time:

> [. . .] any definitive evidence of the overall effectiveness of 'e-learning' compared with more conventional methods. This is not to say that this medium is ineffective but rather to say that there is little systematic and empirical work to show evidence of its evaluation (Mehanna, 2004, p. 280).

This is what is to be tested here: the use of a medium in the classroom.

As what is at stake for e-learning is its effectiveness, this means a requirement for online tested projects, with a tailor-style ambition: the idea that it is possible to have multiple scenarios to fit the needs of multiple individuals:

> Different students have different preferred ways to learn. Some may understand quickly through images, others may prefer texts and readings. Some may deal well with theories, others may learn through experiments and examples. By gaining insights into different learning styles, it offers means to design and provide interventions tailored to individual needs (Truong, 2016, p. 1185).

Though Truong's introduction gives an insight into what an online user-model-based system could be, it confines the adaptive part to the ways to learn: images, texts, readings, etc. It does not tackle the real stakes of an adaptive system: individual differences cannot

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only be taken into account through learning strategies and cannot only be based on subject preferences. It also has to be based on subject performance, which is the core of an adaptive system. The effectiveness of such a system has been established in several studies, such as Di Giacomo *et al.* (2016), Yang *et al.* (2014), etc.

Vandewaetere *et al.* (2011, p. 119) identify three types of adaptive learning:

(1) macro-adaptive instruction;

(2) aptitude-treatment interaction; and

(3) micro-adaptive instruction.

Macro-adaptive instruction corresponds notably to mastery learning: the learner goes at their own pace, in the sense that they have additional instructions or additional support until they achieve mastery on the test. Aptitude-treatment interaction is a more comprehensive system of instruction in the sense that it tries to take into account individual aptitudes and characteristics: for example, one of its principles is that anxious students prefer highly structured systems of learning. Thus:

> Snow (1980) defines three levels of control, complete independence, partial control within a given task scenario, and fixed tasks with control of space. Several studies have shown that the success of different levels of learner control is strongly dependent on the students' aptitudes, e.g. it is better to limit the control for students with low-prior knowledge (Mödritscher *et al.*, 2004).

The last type, micro-adaptive instruction, is the one we are interested in here, as it fitsadaptive e-learning environment. Indeed, micro-adaptive instruction "*diagnoses learner's specific learning needs during instruction and subsequently provides appropriate instructional prescription for these needs*" (Vandewaetere *et al.*, 2011, p. 119). This means that this type of model is dynamic and can fit into a classroom environment, enhancing the possibilities of teacher–learner interaction, as it creates a tutoring system, which can be handled by the teacher, thus putting in place a blended learning system (Kakosimos, 2015). On the one hand, as the system provides adaptive content to the learners, the teachers can provide feedback individually or to groups of students, and on the other hand, the system creates the content environment which fits the abilities of each learner without any external intervention.

This typology helps to orientate the research about adaptive learning in two directions. On one side, there is the approach: what type of system of instruction? On the other side, there is the content: what type of exercises? At which rate? What is the main entry for the learner: An entirely adaptive system? A mixed system with a test to evaluate the learners' level of competence and then adapted exercises with regular check tests to re-evaluate the learners' level? In any case, the goals remain the same: to be able to identify the needs of the learners and to provide them with the content adapted to their needs.

1.2 Need to measure performance

It is on the basis of these thoughts that the platform XXXXX (NAME OF THE PLATFORM) launched its first module for the comprehension of implicit information in 2012. It is an online platform accessible from any browser. There are two different parts in this platform: one planned to be used by speech therapists, while the other one is intended for the classroom (so far, primary and secondary school – one project is in progress for universities).

The platform is a type of micro-adaptive instruction system, as defined earlier (Vandewaetere *et al.*, 2011). It allows the learning process to take three forms: evaluation, individual or group training (autonomy) and tutored training. As any micro-adaptive instruction environment, the first requisite on the platform for any learner is to take a first evaluation, which places them on a scale from A (easy) to J (difficult). Once this is

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done, the training they will be given will correspond to their level, which can be regularly re-evaluated. Individual or group training corresponds to a full-autonomy training, while tutored training is interrupted by the feedback given by the teacher after each exercise.

This platform was used to retrieve data about primary-school learners, who used one of the two modules which are currently available online: Implicit (the other module is Vocabulary). Both modules are in French. They match two different goals: a pedagogical one – helping learners with comprehension difficulties without letting down those who are more advanced, and a research one – verifying the effectiveness of an adaptive e-learning tool, which was created to help learners enhance their competences in comprehension.

So far, the platform is used in France and abroad. Since September 2017, every primary or secondary school which has registered has had access to both modules. The case study which follows concerns a pool of pupils from the academic year 2016-2017, all working on the Implicit module (Table I).

2. Enhancing comprehension through adaptive e-learning: a case study

Comprehension is a challenge for both pupils (learning) and teachers (teaching); comprehension is a fundamental and cross-disciplinary competence (Potocki *et al.*, 2013): pupils need this competence to develop their capacities in the other domains and teachers need to be able to adapt to the individual differences – that is, individual competence – of their pupils. One child out of five has difficulties in comprehension [Daussin *et al.*, 2011; Cnesco (Conseil National d'évaluation du Système Scolaire), 2016]. And those difficulties affect their adulthood: 21.6 per cent of adults in France have performances equal or inferior to the most elementary level in reading [OECD (Organisation for Economic Co-operation and Development), 2013]. In this report, the cognitive skills of adults are directly related to a certain number of facts, such as their level of education, job, wage, etc.

Two different levels of comprehension can be found in a text and readers need to master both of them: understanding the explicit and the implicit information. So, to understand a text and, thus, build a coherent mental representation of the situation in the text (Graesser and Clark, 1985; Kintsch and van Dijk, 1978; Perfetti, 1999; Trabasso *et al.*, 1984; van Dijk and Kintsch, 1983), a reader needs to be able to:

- establish connections between the literal and explicit pieces of information;
- produce the missing information or inferences, that is, deducing certain elements through details of the text or through ensuring consistency between a text and their general knowledge.

To be a proficient reader, you have to master both of them. But what differentiates a high level from a low level learner in comprehension is not the ability to answer the literal questions about a text, but the inferential questions. Indeed, the pupils who understand the less are the ones who produce few inferences (Cain and Oakhill, 1999). So, to help those with a low level in comprehension, teachers need to help them establish the connections, the coherence between the different sources of information available in the text and enable them to express the implicit information in an explicit form.

Year	2013	2014	2015	2016	2017
Number of schools	154	422	647	629	992

Table I. Number of users (schools) per year on the platform TACIT

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2.1 Comprehension and e-learning

Comprehension is a complex task, which requires multiple competences. We have already quoted two of them: as a reminder, understanding the literal information and producing inferences – inferences which can be deduced from a text but which, from a literal point of view, are missing. Of course, these are not the only competences at stake in a comprehension activity.

Ecalle and Magnan (2015) show that there are also two types of processes which enable a learner to understand a text: those which concern the phonological and orthographic identification of the words, and those which imply a syntactic and semantic knowledge. Thus, the comprehension of a text cannot be limited to the understanding of the explicit and implicit parts; it has to be defined through the multiple competences needed to perform the task: decoding and identifying the words, vocabulary, morphology, syntax, semantics and the construction of inferences (Bianco *et al.*, 2014). In this study, we have chosen to focus on the implicit task, that is, the production of inferences, as it is the discriminative factor in terms of comprehension (see above).

The idea that a focus on the implicit task considerably improves the level of comprehension has also been developed in more detailed studies – some directly concerning French (Rémond, 2007; Emin, 2003). Those studies also show that implicit tasks are complex from a content point of view, but they are also complex from a learner's competence point of view. Rémond (2007, pp. 19-20) shows that learners can be split into four groups regarding their results in implicit tasks:

(1) Level 1. 90 per cent of pupils "know how to find explicit information and are able to make simple inferences".

(2) Level 2. 60 per cent are also "able to make inferences and simple interpretations from information within different parts of the text".

(3) Level 3. 26 per cent are even "able to make inferences about characteristics of characters and places from the text and know how to justify them, through personal knowledge and experiences. They understand simple metaphors".

(4) Level 4. 9 per cent also "know how to interpret characters' intentions, feelings, behaviours from the text, and are able to understand concepts such as find out the theme".

This study gives us some insight into one of the difficulties linked to the question of inferences: there is an important diversity in the learners' level and in the inferences. In her results, Rémond (2007) identifies several types clearly: place, time, feelings, etc. On top of those factual inferences, Quaireau *et al.* (2016) define eight other types of inferences.

2.1.1 Types of inferences.

> Inferential language requires children to use their language skills to infer or abstract information by inferencing or analysing, as occurs when a teacher asks a child to predict what a book might be about (e.g., "What do you think will happen in this story?") (Zucker *et al.*, 2010, p. 66).

This means that children have to work out the answer from hints and clues – more or less explicitly expressed – from the text: so, the text has to be read carefully, and personal knowledge and experiences may be needed to draw conclusions from those hints and clues.

As specified by Hall (2015), "*Researchers have proposed a number of inference taxonomies (. . .) and consensus as to a definitive taxonomy has not emerged*". We sum up the inference classification used on the platform XXXXX in Table II.

2.1.2 A need for tools. Most of the e-learning environments existing in French on the text comprehension matter do not concentrate on the question of implicit information. But, as underlined before, the learners who understand the less when reading a text are also the

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Types of inferences	Definition	Example
Grammatical – anaphora	Those inferences allow the reader to link a word used as replacement or substitute (such as a pronoun) to its referent (Lefebvre *et al.*, 2012, p. 11)	A car crashed into a tree, which was an old oak. Given its state, it will never run again What does "it" represent? [The car]
Grammatical – linguistic marks	Those inferences allow the reader to identify information from signs of gender, number, plural and singular	I saw Jenny and Tom last week. She is a doctor now Who is a doctor? [Jenny]
Syntactical	Those inferences allow the reader to deduce information through the place of the punctuation	"Panda. Large black-and-white bear-like mammal, native to China. Eats, shoots and leaves" (Truss, 2003) What does the panda eat? [The text does not enable us to answer]
Hypothetical/conditional	There are elements in the text allowing the reader to make a hypothesis, or which condition the answer to the question	When I grow up, I'll build a castle with four towers How many towers does my castle have? [None]
Numerical	The answer can be deduced from calculation	There are ten turns in this game. I've won four, and lost three. If I win another one, I'll be sure to win the game How many turns are needed to win? [five]
Global semantics	The answer can be deduced from the interaction between the meaning of the words and general knowledge or ability	In Jane's family, women have been teachers for three generations What was the job of Jane's grandmother? [teacher]
Local semantics	The answer can be deduced from the hints and clues which can be derived from the meanings of a few keywords	After the race, Gillian got a gold medal Why did Gillian get a medal? [Because she won the race]
Spatiotemporal	The inferences concern elements regarding spatial or temporal information	The day after tomorrow is the beginning of the week Which day are we? [Saturday]

Table II. Inference classification used on the platform TACIT

ones who produce fewer inferences (Cain and Oakhill, 1999). Thus, with the creation of a new tool, such a fact compels to take into account the two following pedagogical imperatives: helping those who produce fewer inferences and encouraging those who already produce more inferences to go further. On the one hand, the system must propose standardized summative evaluations to know the competence level of learners precisely at different points in time, and on the other hand, it must also include formative assessments, to incorporate learning progressions (Black *et al.*, 2003; Heritage, 2007).

To take account of those individual differences, an adaptive environment needs to propose further help for those who need it. Producing inferences implies being able to link the clues and hints from the text: this means that the attention of the low-level learners can be directed towards those clues to help them produce the inference. The two main solutions used on this platform come from the research on attention (Posner, 1990). There are two types of attention:

(1) exogenous attention, which is related to salient events present in the environment (on the platform, we propose to use words highlighted in blue); and

(2) endogenous attention, which appears when a person decides to pay attention to a part of their environment, according to a pre-determined goal (on the platform, we propose preliminary questions to help answer the main question).

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Other options are available to adapt training, especially for low-level learners. First, there are two types of training:

(1) An "autonomy" mode: pupils respond to the exercises at their own pace on their respective computers, the teacher can monitor their individual progress on his/her control computer.

(2) A "tutored" mode: here, pupils respond individually and at the same time to the same exercise. Teachers visualize who has chosen which answer and can then ask the pupils to justify their choices. The same exercise can be submitted again to see which justification has convinced them.

Teachers can also adjust the number of training exercises (5, 10, 15 or 20), depending on their pupils' abilities, to make sure that the number of exercises will not impact on their pupils' attention negatively: "*the duration of effective daily practice that can be sustained for long periods is limited, and [...] according to teachers and training instructions, it is necessary to maintain full attention during the entire period of deliberate practice*" (Ericsson *et al.*, 1993).

Additional parameters such as main question format (MCQ, open-ended question [...]), score display or progress display can be accessed via an advanced settings menu/advanced menu. The modification of the parameters of a training is taken into account immediately and is automatically and instantly reflected on the screen of the pupils. Other options allow teachers and speech therapists to take into account learners with special needs such as dyslexia: different types of fonts and spacing are proposed; for example, extra-large letter spacing can improve reading, particularly dyslexia (Zorzi *et al.*, 2012).

2.2 Methodology

Each of the projects which are going to be presented in this article started with the same procedure, which is the creation of exercises. For the module on implicit comprehension, we started with the creation of 1,000 exercises. This number was considered high enough to cover all the possible forms of inferences. The first 200 were submitted to pupils as open-ended questions, with only one instruction: to produce an answer. The purpose was to collect wrong answers, which would be produced by pupils and which, thus, would be consistent with the error strategies they most frequently use. Those answers were then selected as deflectors for the exercises, whose final form was multiple choice questions. Indeed, teaching is helping pupils increase their knowledge, but also modify it, as they may have accumulated mistakes. Thus, having pupils face exercises with error strategies they are likely to use gives them the opportunity to modify those strategies as they become aware of their unreliability (Eryilmaz, 2002).

Each exercise consists of a text followed by an inferential question accompanied by four possible answers – the right answer, two deflectors and "I don't know". Different lengths of exercises – from 1 sentence to 20 lines – are used in accordance with research about working memory such as Delage and Fraenfelder (2012): the average length of exercises is a direct parameter of the difficulty of the exercises, as it loads the text with information and it can also be linked to the use of complex sentences (use of adverbial clauses, relative clauses, etc.). In the case of inferences, using a small amount of sentences in an item allows a focus on a particular clue and not on a multiplicity of them. But, as pupils acquire more inference skills, the longer exercises require less effort and become more enjoyable for them. That is why the platform offers a wide range of different lengths of exercises for all competence levels.

Once the pupils' error strategies were established, the 800 exercises remaining were entirely written by the researchers engaged in the project and with the precious help of some volunteer teachers. The 1,000 exercises were then presented to 2,300 pupils, aged from 7 to

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14 – age-groups which correspond to 4 years of primary school and 4 years of secondary school (collège). The aim was to create a scale of difficulty, according to the Item Response Model (IRM), which enabled to create several summative evaluations, which assess learners' competences in a similar way.

Item response theory (IRT) represents an important innovation in the field of psychometrics. It is the psychometric theory underlying many major tests and standard evaluations nowadays. Unfortunately, these IRMs are not easily accessible to psychological researchers and instructional designers, but they have many important research applications. The IRM are statistical models which allow researchers to represent both the learners' level of competence and the level of difficulty of the exercises on the same continuum. Though they are not very much used in applied psychometrics in France, they enable researchers to create adaptive pedagogical systems, where the exercises are selected according to the child's level of competence. The model which was used here is the Rasch model: "*the examiner can use the target person's performance on such a variable segment of self-chosen items to estimate his ability [. . .], the process is self-tailoring. As the target person takes the test he finds for himself the items in the test booklet of difficulty best for him*" (Wright and Douglas, 1975, p. 2). The model was first tested using RLRsim-package (Exact Restricted Likelihood Ratio Tests for Mixed and Additive Models) in the R environment. However, the module is only entirely adaptive in the speech therapists' version, not in the teachers' version used here: for this study, it is merely partially adaptive as the summative evaluations establish a competence level and then the training exercises submitted will correspond to that level.

Once the exercises had been created and their difficulty established, a study was put in place for pupils in primary school on the academic year 2016-2017 (second to fifth grade). The children's repartition was as follows, in Table III.

Before going into further details, it has to be understood that the module is divided into two types of items: the evaluation items, which are gathered into five groups of 20 items, and the training items, which correspond to the rest of the items. The difference between the evaluation and the training items is that the evaluation items are perfectly distributed on the scale of difficulty and allow to define pupils' levels on a corresponding scale of competence. The training exercises are not used to identify pupils' levels of competence, but they are nevertheless regrouped by level of difficulty. Thus, once a pupil has taken the first evaluation, they can then take training exercises which will match the level of difficulty identified by the evaluation.

In the case of our study, we tried to model the variance of results for the last evaluation the learners took during the academic year. We used a stepwise Bayesian linear regression. The method chosen was a stepwise in which the choice of predictive variables is carried out by an automatic procedure. More precisely, the stepwise selection is the forward stepwise selection. In other words, it is an automated procedure that can identify useful predictors during the exploratory stages of model building. This method is particularly useful when dealing with multiple independent variables. To determine the most probable model, we used the Bayes Information Criterion (BIC) and we chose a definite number of independent variables, which had a presumed link to the dependent variable (i.e. the last evaluation

Table III. Distribution of pupils by school level and gender in the present study

	Primary school levels				
	CE1	CE2	CM1	CM2	Total
Female	432	1,414	2,209	2,719	6,774
Male	444	1,469	2,219	2,934	7,066
Total	876	2,883	4,428	5,653	13,840

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results). As we used a Bayesian linear regression, we started by standardizing the predictors before calculating the terms of the interactions.

We chose the starting level of learners, the number of training exercises and the length of the trainings (calculated in days) to check if the progress we presupposed was really linked to the use of the platform. As our analysis focused on a relatively substantial sample (N = 13840), we also integrated complementary variables. Indeed, Cohen (1992) and Hair *et al.* (2006) showed that the number of observations directly determine the maximum number of variables accepted by a statistical model. The more observations there are, the easier it is to include new variables in the model. The other two potentially confounding variables we included were the gender of the participants and their school level – two variables which were shown as significant in studies such as PIRLS 2016 (Colmant and Le Cam, 2016).

2.3 Results

The Best Regression Model indicates that the last evaluation results are predicted by:

- The first evaluation results: the last evaluation results are logically dependent on the first evaluation results, that is, the final score depends on the competences of each pupil before they start training.
- The length of the training period: the longer the training period, the higher the final results.
- The school level: on average, the higher the school level, the better the results in the final assessment.
- The gender: female learners obtain higher final results, which is consistent with results generally found in other research (PISA 2012; PIRLS 2016).
- The number of training exercises the learners took: pupils who have trained the most (i.e. the ones who have taken the greatest number of training exercises) obtain higher final results.
- An interaction between the first evaluation results and the length of the training period: the number of training days has a larger effect size for pupils with a low initial level compared to pupils with a higher initial level.
- An interaction between the first evaluation results and the gender: progress is greater for pupils with a low initial level, especially for female learners.
- An interaction between the first evaluation results and the school level: a high initial level favours the last evaluation results especially as the pupils are in the highest school levels. Besides, the gap between the low-level learners in CM1 and CM2 (fourth and fifth grade) is not as big as the one between the high-level learners in the same years.

Finally, the regression shows that the most probable model, for our data, is the one which accepts the random effects (tested by simulation with RLRsim). A multi-level analysis shows that the size of the effects that we mentioned above is reduced or increased by the dynamic of each class (effect of the type of pedagogical style, general atmosphere of the class, etc.).

This model explains 48 per cent of the variance (Residual standard error: 0.69 on 13,777 degrees of freedom; Multiple R^2: 0.4858, Adjusted R^2: 0.4854; F-statistic: 1085 on 12 and 13,777 DF, p-value: $<$2.2e-16).

The key elements are the effect of the training period and the different interactions mentioned above. The following graphs will allow us to detail those elements more thoroughly.

In Figure 1 (left), there is a log transformed variable: as defined by Kenneth Benoit (2011), "*logarithmically transforming variables in a regression model is a very common way to handle situations where a non-linear relationship exists between the independent and dependent*

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variables". More precisely, it means that the mass of data for the independent variable are bunched at lower values (the data distribution is consequently much roughly symmetric). On this graph, we can see that the more exercises the learners do, the higher the last evaluation results are. This result shows that the observed progress is definitely linked to the use of the platform and confirms our assumption – the effectiveness of the adaptive e-learning tool. The second graph (right) underlines the fact that the low level learners are the ones who make the most progress and especially when they trained a lot during the academic year.

The third graph (Figure 2; left) shows again that the low-level learners are the ones who make the most progress, and this progress is more salient for low-level female learners.

Again, the fourth figure (Figure 2; right) shows that the learners who initially had the lowest level are the ones who make the most progress and the higher the school level, the more salient the results.

This last figure (Figure 3) introduces a more comprehensive point of view, through a multi-level analysis. It shows that the size of the different effects we have demonstrated is moderated (reduced or increased) by the dynamic proper to each class. Indeed, factors external to the platform have to be considered such as the effect of the multiple pedagogical styles put in place by teachers, the general atmosphere of the classroom depending on the relationship between the teacher and the pupils but also between the pupils, the frequency of use of the options proposed by the platform, etc. For example, in the case of pupils with a low initial level and who do not train a lot, going at their own pace could also mean receiving appropriate help to get started, such as further explanation from the teacher or help provided by options embedded within the platform, such as preliminary questions or highlighted keywords. For instance, we could take the following example (already presented in 2.1.1.): "When I grow up, I'll build a castle with four towers. How many towers does my castle have? [None]". The preliminary question for that item could be: "Does the utterer already have a castle?". Or the other possibility could be to highlight the "ll", indicating the use of the modal WILL to help the pupils realize the direction their reasoning should take to answer that particular item and question. Another possibility would be to place this exercise in a tutored training session. Thus, each pupil on their computer would have to answer the exercise first. In the meantime, the teacher could see on hihe/sher screen who has answered correctly or not and, in this last case, which erroneous answer was chosen. Then, once everyone has answered, a time for discussion, questions and explanations might follow, led by the teacher.

3. Conclusion: e-learning environment and effectiveness

Adaptive e-learning is an effective solution regarding comprehension for primary-school learners. The feedback we have from teachers is that the platform blends easily into the lessons, enhancing the game aspect while achieving its objective: enhancing the learners' performances in reading comprehension. The progress linked to the use of the platform shows how useful adaptive solutions can be for the comprehension of implicit information. This progress is on average more salient for those who train for a longer period and for the oldest pupils in this study (those belonging to CM1 and CM2 classes, that is, CM1 and CM2 being the last two years of primary school in France, respectively, fourth and fifth grade). Besides, pupils who have the most difficulties are the ones who progress the most on the platform, and this progress is even more salient for female pupils.

However, some questions remain unanswered with this first case analysis, and what remains to be studied is:

- Is the platform efficient for all school levels? For the moment, only data from primary school learners have been retrieved and analyzed, though the platform is

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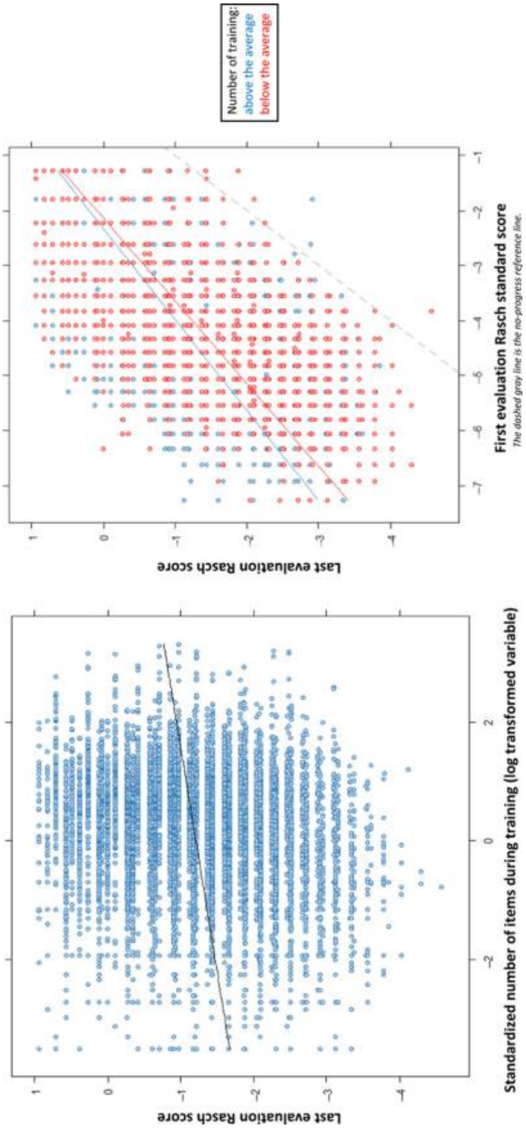

Figure 1.
Effect of the training period length (left); interaction between the first evaluation results and the training period length (right)

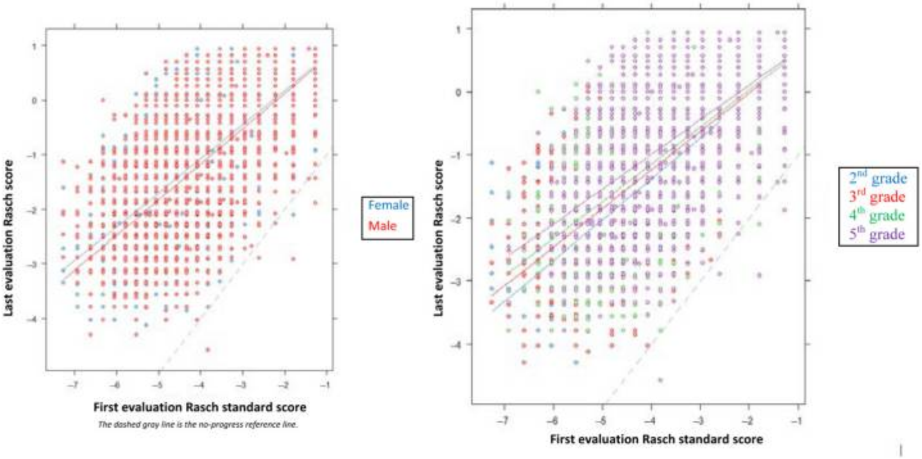

Figure 2.
Interaction between the first evaluation results and the gender (left); interaction between the first evaluation results and the school level (right)

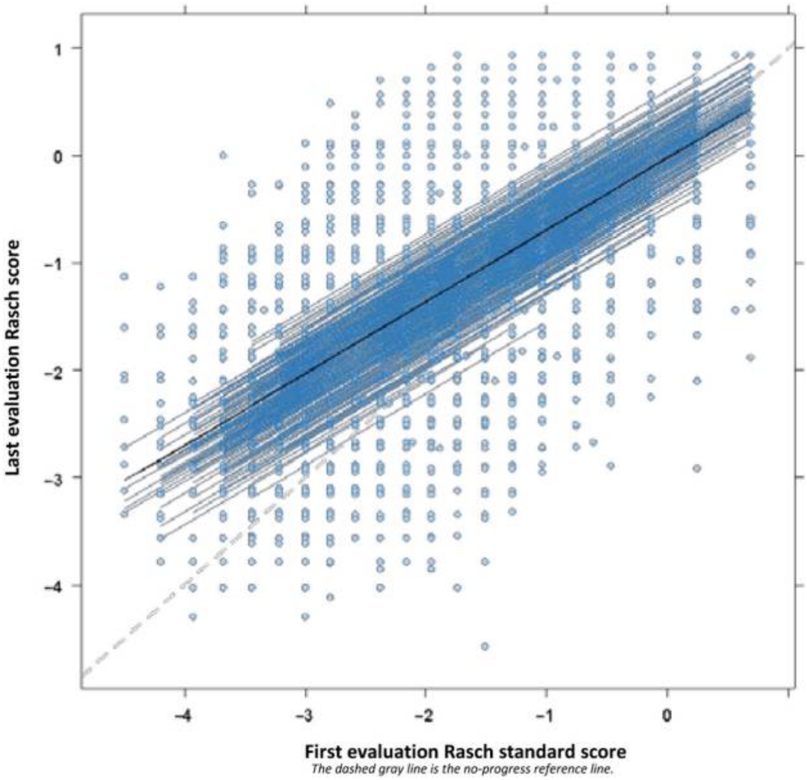

Figure 3.
The most probable model, for our data, is the one which accepts the random effects

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also used by secondary school learners. Substantial data are already available for analysis to answer this question.

- Is the platform efficient for every competence? For instance, another module remains to be studied: Vocabulary. As in this case, the retention is generally bound to a certain number of encounters pupils have with a particular word or expression. Here too, substantial data is waiting for analysis for further scientific publications.
- Is adaptive e-learning efficient for full-autonomy sessions? A module in English Grammar has been created and should be implemented by the end of 2019. The targeted learners are university students, and the objective is to help them reach the B2 level (See Common European Framework of Reference for Languages) they are supposed to have when enrolling in university. The module in implicit is generally used within a classroom context, but the university curriculum as well as the size of student groups may not always allow the platform to be used in a similar way. Thus, the effects of a full-autonomy session remain to be determined, along with variables which may play a major role in the success of such a module. About those external variables, researchers such as Andrew Martin (2007) have already highlighted the importance of motivational variables, in an educational context, such as self-confidence, learning, schooling, perseverance, planning and monitoring. Others have stressed the importance of procrastination (Michinov *et al.*, 2011) in online learning environments.

As Wijekumar *et al.* (2013, p. 366) pointed out:

> Even though scholarly journals are full of technology-based solutions that appear to produce large effect sizes in small studies, many do not reach their forecasted potential in large scale randomized controlled trials.

So far, the platform has reached an equilibrium between researchers', teachers' and learners' expectations and the implemented adaptive environment has been shown to be effective for enhancing reading comprehension performance for primary school learners.

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