The digital book: a tool to help university students succeed?

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Abstract

In this paper, we evaluate the effects of two modalities of use of digital books by university students: discovery of the digital book before the course vs. discovery of it after the course. During the experiment, we recorded the traces of the students' activity in the digital book. Our study revolves around 4 research questions (Q1, Q2, Q3 & Q4). If students make significant progress during the pedagogical sequence (Q1), it highlights that moment of use e-book does not have an effect on the students' performances (Q2). However, some student behaviours in the eBook vary depending on when the eBook is used (Q3). A regression analysis between these behaviours (process) and learning gains (performance) shows that consulting additional info/glossary, expansion slideshows and verification of responses would be success factors (Q4).

Keywords

E-book, communication, experimental design, help for success, university

Résumé

Dans cette contribution, nous évaluons les effets de deux modalités d'utilisation du livre numérique par les étudiants universitaires : avant le cours vs après le cours. Au cours de l'expérience, nous avons enregistré et analysé les traces de l'activité des

étudiants dans le livre numérique. Notre étude s'articule autour de 4 questions de recherche (Q1, Q2, Q3 et Q4). Si les élèves font des progrès significatifs pendant la séquence pédagogique (Q1), nous observons que le moment d'utilisation du livre numérique n'a pas d'effet sur les performances des élèves (Q2). Cependant, certains comportements des étudiants dans le livre électronique varient en fonction du moment d'utilisation du livre électronique (Q3). Une analyse de régression entre ces comportements (processus) et les gains d'apprentissage (performances) montre que la consultation d'informations complémentaires/glossaire, l'agrandissement des diaporamas et la vérification des réponses seraient des facteurs de réussite (Q4).

Mots-Clés

E-book, communication, design expérimental, aide à la réussite, université

Introduction

In recent years, the educational technologies have become an important part of universities. A large majority of students use a laptop or digital tablet in their learning (taking notes, reading syllabuses, carrying out teaching activities, etc.). From the inception of the e-book, in the past years, growth in the e-book market has exploded (for example, Mordor Intelligence, Statista)[1] (Walton, 2013). It seems relevant for teachers to take advantage of this craze to offer students tools that can potentially promote learning.

Indeed, the digital book seems to be a particularly interesting tool to offer learners because it allows them, on the one hand, to access textual information and, on the other hand, to benefit from complementary content enriched by media (Boumazguida, 2020).

In order to objectify this, Roussel et al. (2017) provide a synthesis based on the analysis of several research studies on the use of digital books in higher education. This synthesis shows that the majority of the benefits identified by learners are based on the notion of interactivity. Users of digital books would appreciate their features, components and the ability to interact.

To encourage interactivity, the teacher can integrate tools with cognitive potential such as video, integrated exercises, audio explanations. Potential cognitive tools correspond to a computerised environment that can be integrated into training situations to promote learning. Cognitive tools, on the other hand, refer to 'an environment whose cognitive effects have already been actualised within a particular context and according to certain

1 Statista and Mordor Intelligence are 2 online portals offering statistics from the economic sector.

uses' (Depover, Karsenti, & Komis, 2007, p. 4). Temperman and De Lièvre (2009) refer to these authors to emphasise that depending on the relevance of the learning context, the tool selected by the teacher will be 'likely to meet the real needs of learners and, at the same time, help them develop different types of skills' (p. 181).

The analysis of the uses of learning actions objectified by the potential cognitive tools proposed in the digital book can be relevant to highlight how students learn. A large body of research in education science shows the value of the study of actions carried out by learners in order to understand their ways of learning (Bojuwoye et al., 2014; Boumazguida, 2020; Rafferty, LaMar, & Griffiths, 2015; Robal et al., 2018; Rowlands et al., 2007).

This study of (inter) actions can be carried out through trace analysis. Analysis of traces (learning analytics) and study of students 'progress have been led to result in statistical analysis which gives some explanations about our research. The recording of the user's trace is qualified by computer scientists as raw data or more commonly as logfile. Boumazguida, Temperman and De Lièvre (2018) explain that it is essential to look for indicators in order to understand how a learner progresses through the training system. An indicator is "a variable in the mathematical sense to which a series of characteristics is attributed…]. Each indicator, as a variable, can be independent or dependent on other variables, or even on other interaction analysis indicators" (Dimitracopoulou & Bruillard, 2006, p. 8). For Li et al. (2015), the analysis of behaviours based on indicators can concern various complementary aspects that may correspond in particular to learners' social interactions (messages published on a forum, creation of a discussion thread, etc.) or to their actions in a knowledge structuring space (editions, consultations, modifications in wikis, etc.). Learning analytics therefore enables us to learn more about learners through the multiplicity of interactions that they can generate within learning devices.

In this research, we propose to describe and implement an evaluation approach based on the traces left by learners during their use of a digital book.

Furthermore, as Coiro (2020) points out, it seems important for teacher-researchers to improve their understanding of how to assess indicators of understanding and learning while diagnosing and supporting readers in digital spaces. Thereby, this experimental research is in line with the work of Roussel et al. (2017) and Stirling and Birt (2013) who respectively studied the use of the digital textbook by teachers and students and compared the use of an enriched multimedia e-book with traditional teaching methods. As put forward by Louay Salam, Piau-Toffolon and May (2017), we believe that the digital book is a tool that can enable students to quickly become affiliated with the academic world and thus be able to succeed there.

We describe the way in which the students will use the digital book, and more precisely, the different tools with cognitive potential that it integrates according to the

pedagogical modality chosen by the teacher: provision of the digital book before the course vs. discovery of the book after the course. Our ambition is to highlight which of these two pedagogical modalities could improve learners' performance.

To answer this question, we browse a screen-casting process to evaluate real uses (achievement of exercises, slide/video reading…) of students who read an e-book.

In other words, the purpose of this research is twofold:

1. To compare the two approaches and their effects on the students' performances.
2. To identify uses of digital book reading can impact learners' performances.

Our aim is to inform teachers of the added value of digital books depending on the teaching context.

The remainder of this document proposes first of all, a literature review relating, on the one hand, to the use of digital books and, on the other hand, to the use of tools with cognitive potential in education. Next, we describe the learning environment and develop the research methodology. We then present our results. Finally, we conclude with a discussion and propose some avenues for reflection.

Digital reading

The presence of the digital screen in everyday life, whether in a professional or personal context, pushes everyone to read on the screen. Digital reading appears to be the most relevant way to spread knowledge, like a universal library. As Mason (2018) explains, citing Bråten and Strømsø (2011) and Stadtler and Bromme (2013), "in the Google era, students are very often required to process and comprehend multiple textual sources to acquire knowledge and gain a deep understanding of a topic or issue" (p. 1). Indeed, already in 2004, Bélisle pointed out, given the multiplicity of digital reading media (laptop, television, computer and e-book), each on-screen reading experience is different, which leads to assets and constraints specific to each type of device. Digital books offer a wide range of features for readers.

These functionalities are proposed to offer them the most pleasant reading experience possible. These features can affect the behaviours of readers who will have the choice to use them or not. Reading behaviours are determined by the nature of the aims of readers. The majority of readers do not use any e-books' function as a dictionary or glossary, which although are appreciated for easy access to definitions, are not used. However, readers seem to appreciate the annotation in the digital book because this is an action similar to a gesture that can be realised in a traditional book. They annotate their e-books with symbols (question mark, exclamation mark…), circle or sentences (Cuillier & Dewland, 2014; Dobler, 2015; Gharbi, 2006). Readers who read the text by the use of 'search function' also use flashback to find elements that are in the beginning of the e-book. This behaviour can

be explained by the absence of contextualisation in results provided when they use 'search function' (Muir & Hawes, 2013).

Besides, digital books propose a lot of audio or video resources (speeches, music, pictures, animations….) (Mutalib Embong et al., 2012). They have significant potential of multimedia resources that may impact on the strategies used by university libraries in terms of communication of scientific writing, which could influence teaching and learning (Dujol, 2016).

Nevertheless, we have to be careful with reasons to use this function because of the motivations of readers to discover the options which are proposed by the digital book (Gharbi, 2006). According to Saemmer (2007), the real question is related to the emergence of new forms of comprehension associated not with the in-depth reading of texts, but rather with the establishment, for the reader, of links between textual and multimedia or hypertextual elements. Bélisle (2011) emphasises the concepts of ergative reading and immersive reading as contrasted by Vandendorpe (2011). The latter defines immersive reading as a more linear reading in which the reader is immersed in real immersion with the text. According to this author, ergative reading corresponds to a reading centred on the reader's action. Readers will read erratically when they want to produce new writing, take notes, perform specific tasks, highlight in the text, flip through the book, share information, etc. The reader will have an ergative reading when he or she wants to produce new writing, take notes, perform specific tasks, highlight in the text, flip through the book, share information, etc. Readers have freedom of action and can autonomously determine their own learning path by choosing to read or navigate from one web page to another. This process allows them to mobilise a set of cognitive abilities that make learners active, even creative, since they no longer depend on the 'diktats' imposed by the author. Ergative reading would therefore lead the reader to mobilise the text 'in its materiality and to orient its 'gestures' towards action leading, ultimately, to an "interactive discourse", the ultimate level of the repertoire of gestures linked to digital reading'[2] (Taous, 2020, p. 8). Vandendorpe (2011) also states that ergative reading depends entirely on the interests of learners and the fact that each learner will have a path of his or her own.

Furthermore, Saemmer (2007) emphasises that there is no real compartmentalisation between the different categories of reading, since, for example, ergative reading can be reflective and contemplative reading can be based on the ergative reading through textual elements.

To highlight the advantages and disadvantages of the digital book in a higher education context as identified by students, we propose the following table taken

2 Our translation of « dans sa matérialité et à orienter ses « gestèmes » vers une action conduisant, en dernier ressort, à un « discours interactif », niveau ultime du répertoire de gestes liés à la lecture numérique » (Taous, 2020, p. 8).

from the research of Roussel et al. (2017). In their research, these authors analysed a large number of works from mainly Anglo-Saxon scientific journals. As they explain, the 'authors' column determines, as it were, the extent of the result obtained. The reader can thus, by visualising this number, appreciate its importance when compared to all the elements presented[3] (p. 20).

TABLE 1

Advantages and disadvantages of the digital book according to research by Roussel et al. (2017)

Features		Perceptions		Authors
General resources	*Lecture*	Causes eye fatigue.	-	Asunka, 2013), (Atlas, 2013), (Baek et Monaghan, 2013), (Cuillier et Dewland, 2014), (Daniel et Woody, 2013), (Dobler, 2015), (Dwyer et Davidson, 2013), (Elias et al., 2012), Falc, 2013), (Kouis et Konstantinou, 2014), (Laosethakul et Yajiong, 2011), (Marques de Oliveira, 2012), (Millar et Schrier, 2015), (Parsons, 2014), (Phi- lip et Moon, 2013), (Rockinson-Szapkiw et al., 2013), (Schoch et al., 2006), (Vernon, 2006)
	Reading time	No reduction in study time. Constitutes an irritant for users.	-	(Falc, 2013)
	Use of zoom	Offers the possibility of adapting the text content to the screen or to one's reading ability. High perceived usefulness.	+	(Schomisch et al., 2012)
	Table of Contents	Allows you to find definitions of the main concepts in the manual.	+	(Falc, 2013), (Johnston et al., 2015), (Muir et Hawes, 2013); (Petrides et al., 2011)
Resources of an informative nature	*Use of the glossary*	Allows you to find definitions of the main concepts in the manual.	+	(Chaudhri et al., 2013), (Falc, 2013), (Johnston et al., 2015), (Muir et Hawes, 2013), (Parsons, 2014), (Schugar et al., 2011)

3 Our translation of « auteurs détermine, en quelque sorte, l'ampleur du résultat obtenu. Le lecteur peut ainsi, en visualisant ce nombre, apprécier son importance lorsque comparée à l'ensemble des éléments présentés » (Roussel et al., 2017, p. 20).

TABLE 1

Features		Perceptions		Authors
Resources of an informative nature	*Additional information*	Gives the opportunity to explain the meaning of a particular term. A dialog box appears when the cursor points to a word or phrase included in the numerical manual.	+	(Muir et Hawes, 2013)
	Internet links	Allow links to external sources and promote research from external links.	+	(Baeck et Monaghan, 2013), (Rockinson- Szapkiw et al., 2013), (Shin, 2014 ;), (Woody et al., 2010)
Explanatory resources	*Slideshow playback*	Are considered interesting by users.	+	(Liu, 2011), (Muir et Hawes, 2013), (Rockin- son-Szapkiw et al., 2013)
	Reading of diagrams	Would promote learning when used for certain types of content (calculus concepts), but few students use it.	+ -	(Bode et al., 2013)
Multimedia resources	*Listening to audio*	These components help students to better understand the content and contribute to a sense of satisfaction.	+	(Baeck et Monaghan, 2013)
	Video playback			
Resources of a formative nature	*Carrying out the exercise*	These components would be in line with the principles of the constructivist approach to learning (autonomy, development of higher-level skills). Allows for a variety of strategies to be used.	+	(Precel et al., 2009) (Falc, 2013), (Liu, 2011), (Parsons, 2014)

We can see in Table 1 that while some e-book features have many advantages for students, others have their limitations and would not necessarily promote learning.

Resources for learning

After describing the characteristics of digital books, we describe the tools with cognitive potential generally integrated in these educational media. We will focus mainly on

multimedia resources (videos, slide shows and podcasts) and resources of a formative nature. It is these resources that have been integrated into the digital book that is the subject of this research.

Multimedia resources

First of all, we focus on the use of multimedia resources such as podcasts and slide shows in a training context. Secondly, we are interested in the use of videos designed and used by teachers in teaching systems (online or offline).

For several years now, slide shows have been used by teachers in universities around the world. Research by Parong and Mayer (2020) has shown that PowerPoint slide shows are effective tools for learning. Compared to technological tools such as immersive virtual reality, this type of support would promote retention and decrease the cognitive load of students. Nevertheless, Paivandi and Espinosa (2013) citing Hébert et al. (2010) explain that while the slide show appears to be a 'learning facilitator', it also appears to 'set up a detrimental distance for learning between the teacher and his students' (paragr. 28).

Podcasting is a way of distributing audio files (podcasts) by the Internet. Podcasts can be downloaded by users. According to Khechine, Lakhal and Pascot (2009) students who listen to podcasts have better performance levels than those who do not use them. Temperman and De Lièvre (2009) estimate that "the real added value of the podcast lies in the pedagogical exploitation of its specific features in terms of the learner's active situation and in the media coverage of the sequences through the judicious combination of information sources to promote effective learning"[4] (p. 18).

Regarding the video, Boumazguida et al. (2018) referring to Roland and Emplit (2015) characterises this media as short audiovisual sequences created by a teacher for students to enable them to deepen, illustrate or contextualise an aspect of a specific point of the course. Cormier et al. (2017), referring to Allen and Smith (2012), Hsin and Cigas (2013) and Kay (2012), highlight the existence of a consensus within the scientific community concerning the pedagogical added value of using video for learning purposes. For them, this type of educational media is a 'highly effective pedagogical tool' (paragr. 8). Moreover, Bishop and Verleger (2013) have shown that learners integrate the content offered in videos better than in text form. However, despite the advantages of videos, learner engagement with the material is limited, which can lead to a superficial understanding of key concepts. According to Bates (2019), in order to make the most of video vignettes, it is important to make learners active by integrating learning

4 Our translation of "la vraie plus-value du podcast se situe complémentairement dans l'exploitation pédagogique de ses spécificités en termes de situation active pour l'apprenant et dans la médiatisation des séquences par la combinaison judicieuse des sources d'informations pour favoriser un apprentissage efficace" (Temperman & De Lièvre, 2009, p.18).

activities into them. Indeed, learners tend to reject videos that force them to analyse or interpret situations, as they prefer teaching that focuses primarily on understanding. Indeed, as Fiorella and Mayer (2018) explain, viewing videos promotes the acquisition of conceptual knowledge as long as learners are offered tasks in which they have the opportunity to mobilise them. Based on this observation, it seems appropriate to propose exercises to be carried out after viewing the video or integrated into it.

Resources of a formative nature

According to Dunlosky et al. (2013), self-correcting questionnaires (or automated assessments) can take different forms: multiple-choice questions, true or false, gap-filling texts, matching exercises, and so on. Bouffard, Pansu and Boissicat (2013) argue that self-correcting questionnaires make it possible to assess learners more objectively and reduce bias and variables that are not directly related to the assessment process. Thobois Jacob (2018), quoting Dunlosky et al. (2013), explains that 'practice tests are probably one of the most effective and useful learning strategies because they benefit learners of all ages and enhance performance in a variety of educational contexts'[5] (p. 5). These authors argue that carrying out tests in the logic of repetitions spaced out over time would be conducive to the appropriation of content by learners. However, they note that, despite the added value of this type of pedagogical approach, it is an action that is less spontaneously used by learners.

This is why it is therefore important to integrate self-correcting questionnaires into training systems so as to stimulate learners' ability to take ownership of the content (Boumazguida, 2020).

Methodological framework

As a reminder, the objective of the research is to evaluate the effects of two modalities of use of digital books by university students: availability of the digital book before the course vs. discovery of the book after the course.

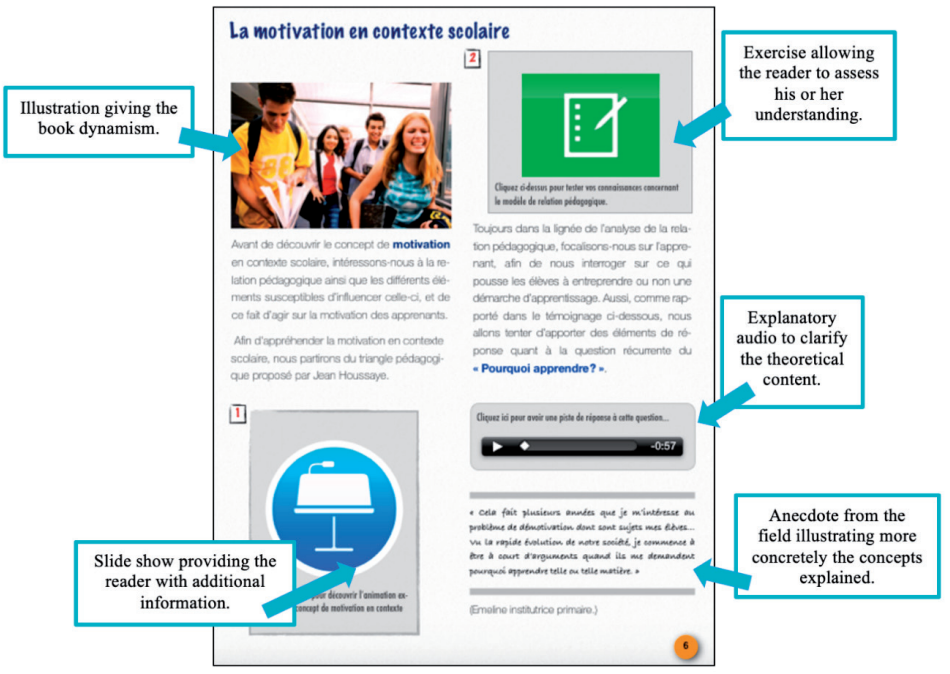
In this section, we describe the methodology of our research. First, we present the learning environment: the digital book. Then, we present the context of our research, the sampling, the experimental design set up. Finally, we specify the different research questions that we will answer in the analytical part of this article.

5 Our translation of « les tests d'entraînement constituent probablement l'une des stratégies d'apprentissage les plus efficaces et les plus utiles parce qu'ils bénéficient à des apprenants de tous âges, renforcent les performances dans divers contextes éducatifs » (Thobois Jacob, 2018, p. 5).

Description of the Learning Environment

Pedagogically, we have relied on the theory of multimedia learning proposed by Mayer (2009) to design this digital book. Technically, the digital book was built using the 'iBook Authors' software and various programs such as 'Learning App' and 'Bookry' (Figure 1). It addresses, in an interactive way, different theoretical contents related to educational sciences. By navigating through the digital book, students benefit from a global view thanks to the table of contents.

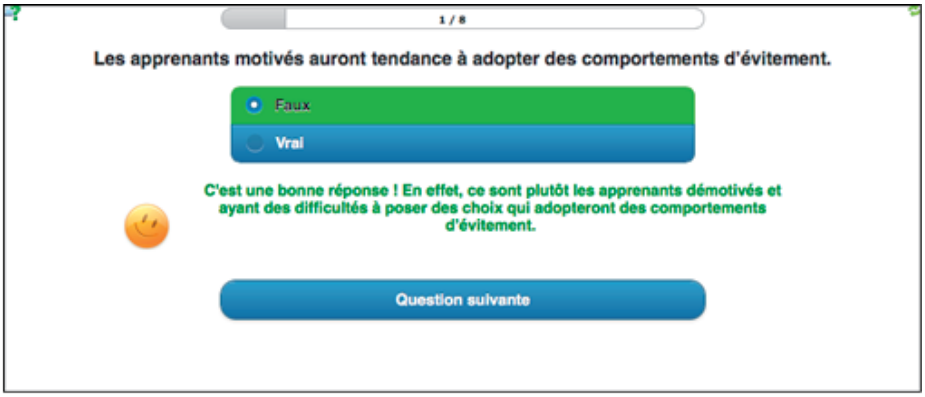
FIGURE 1



Interface of the digital book created for this research

They can either read in an immersive way (from start to finish) or in an ergative way (by choosing the contents). The textual information is punctuated by different media (video, audio, etc.) and exercises (matching exercise, quizzes, true and false, etc.) (Figure 2).

FIGURE 2



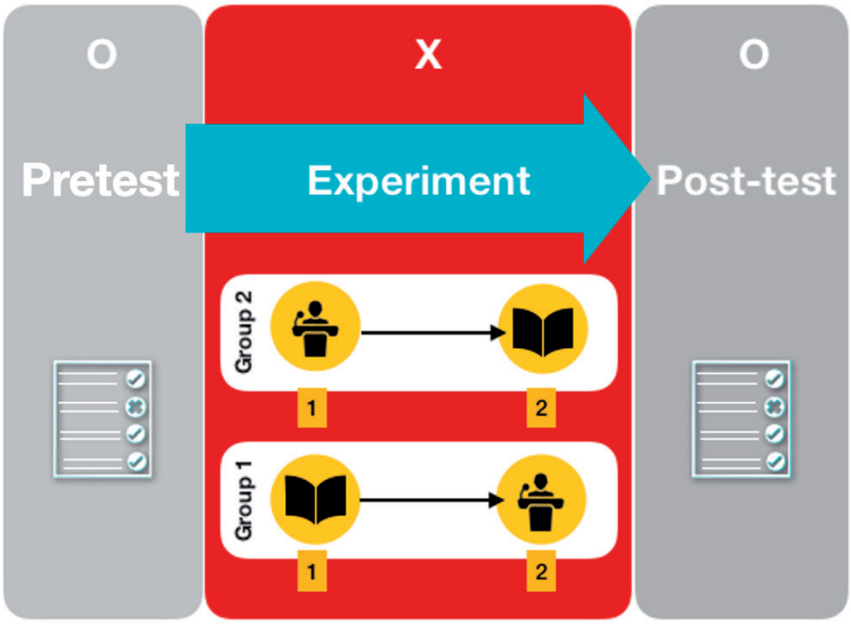
Example of an exercise integrated into the e-book (with feedback)

Subjects and procedures

These subjects are students at the University of Mons in master's degree in Educational Sciences. This sample must be considered as occasional since it does not result from random sampling within a given population. The digital book was entrusted to them as part of a 'General Didactics' course organised at the same university. The experiment was therefore carried out under real learning conditions. Indeed, the theoretical contents addressed in the digital book are part of the 'General Didactics' course. We divided our sample into two groups.

The subjects in group 1 (N =29) first attended the course and then received the e-book. Conversely, the subjects in group 2 (N=27) first read the e-book and then attended the course. In this experimental research, our search feature is classical 'OXO' (Observation 1 – eXperiment – Observation 2). In other words, students have participated in a pre-test, followed the course and used the e-book and participated in a post-test (Figure 3).

FIGURE 3



Experimental design

A pretest to assess prior knowledge

The pretest is a multiple-choice questionnaire with 26 closed questions (Table 2). The pretest questions related to the theoretical contents proposed in the digital book (motivational theories). All students have been the same conditions of answering.

TABLE 2

Examples of questions proposed in the pretest and the post-test

Taxonomic levels	Questions
Knowledge	**Motivation:** ❑ Is a dynamic state resulting from the learner's perceptions of himself and his environment. ❑ Is a static phenomenon related to a lack of control over one's thinking. ❑ Is the degree of mental effort expended by the learner during the performance of a learning activity. ❑ Is a source of information that may be relevant to the learner's self-perceptions.

TABLE 2

Taxonomic levels	Questions
Understanding	**Which of these situations arises from the phenomenon of 'expectation'?** ❑ Peter wonders if he is cut out to be a school headmaster. ❑ Peter wonders if the fame that comes with this new profession will benefit him. ❑ Peter wonders if this 'promotion' is really worth it to him.
Analysis	**Karim was feverish on the day of the test, so he did not perform well.** ❑ Internal, modifiable, controllable. ❑ External, changeable, controllable. ❑ External, stable, uncontrollable. ❑ Internal, stable, controllable. ❑ Internal, stable, uncontrollable. ❑ Internal, changeable, uncontrollable.

We used three taxonomic levels of the Bloom model (1956) to create these items: 'knowledge', 'understanding' and 'analysis'. We did not create questions related to the third level of this taxonomy (application) because the theoretical content, related to the course, proposed in the digital book did not allow the application. Rather, it was intended to promote understanding of content through reformulation, application through deductive reasoning and analysis through inductive reasoning. In addition, we considered these levels to be the most appropriate for our system in that they allowed the learner to establish links with concrete situations proposed in the book (e.g. Anecdotes from the field).

Experimental device and screen casting

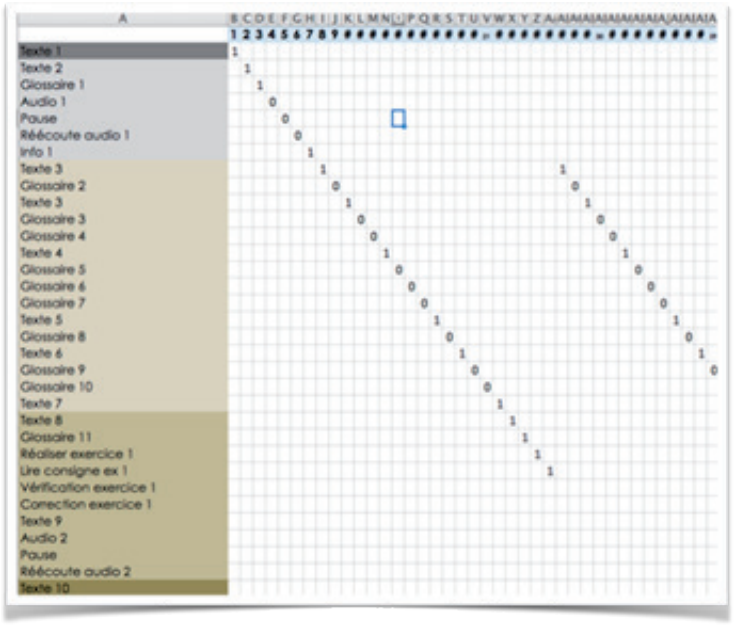
As a reminder, our research has been unfolded in two phases spread according to the experimental group:

- The group 1 has received e-book before face-to-face teaching.
- The group 2 has gone to the course before to use e-book.

The face-to-face teaching was an ex-cathedra course in which students discovered certain motivational theories. In order to collect the traces left by the students during their use of the digital book, we let them tablets (iPad). Each student was able to navigate

independently through the digital book. For two hours, students have discovered e-book in autonomy on digital tablets. We recorded the actions carried out by the learners (screen casting) on the e-book so that we could analyse them afterwards. All actions of them have been codified in an evaluation grid that we have created in Excel before the experiment. Each action carried out by the learners (consultation of chapters, reading of videos, use of quizzes, etc.) was recorded on video. There were as many videos as there were learners. Each of these recordings was manually coded in the grid. This evaluation grid has been mobilised to analyse the way of reading an e-book, according to the modality of use of digital books by university students. We have noted the possibility to do 215 different actions during this digital reading (Figure 4).

FIGURE 4



Coding grid for learners' actions during digital reading

This approach was repeated on the one hand, on the overall actions undertaken by the reader and, on the other hand, on each of the different possible actions. This enabled us to use measurable and quantifiable data in terms of learners' use of digital books. During the experiment, students also had a tool sheet available that could be useful for navigation. This sheet indicated the function of the main interactions that could be carried out in the book. However, the teacher was available in case of problems or simply to answer the various questions that could be asked by the learners.

A post-test to assess the knowledge acquired

After this experiment, students have taken a post-test very similar to the pretest; so, a multiple-choice questionnaire with 26 closed questions subdivided in different taxonomic levels of Bloom's model (1956) as 'knowledge', 'understanding' and 'analysis'. Correction of both was similar to remove the risks of bias.

Research questions

In this research we studied, on the one hand, on comparisons of learning modalities (e-book before the course vs e-book after the course), and, on the other hand, on the analysis of the actions carried out by learners on the digital book in an attempt to highlight a potential effect on their performance. The research questions examined are:

1. What is the progression of learners during the pedagogical sequence?
2. Is there a relationship between the moment of e-book use and the students' performance?
3. Is there a relationship between the moment of e-book use and modalities of use of it?
4. Is there a relationship between students' discovery process of e-book, their initial characteristics and their learning gains?

Results

Our analysis is structured around our four research questions, namely performance, and modalities of use and relationship between 2 variables (availability of the digital book before the course vs. discovery of the book after the course).

What is the progression of learners after the pedagogical sequence?

To answer this first question, we measured student progression on the basis of relative gains (RG) calculations. The calculation of this gain looks a judicious way of assessing a performance gain on the part of the subjects between two observations. It corresponds to the ratio, expressed as a percentage, between the gross gain and the maximum of what could have been gained in relation to the subject's starting level. An equivalent principle also makes it possible to calculate relative loss when a subject's performance declines (D'Hainaut, 1975, cited by Temperman et al., 2017). According to D'Hainaut (1975) there is effective apprenticeship, and therefore a positive effect of apprenticeship, when the 30% threshold is crossed.

In descriptive terms, a comparison of pretest and post-test scores shows that students obtain an average overall score of 40.23% in the pre-test compared to 62.65% in the post-test (Table 3). These results allow us to highlight a learning effect between the pre-test and the post-test. This result allows us to suggest the usefulness of the

teaching system. Analysis of the coefficients of variation (CV[6]) shows a very slight decrease from 27.63% for the pre-test to 26.67% for the post-test. Although this difference is quite small, we assume that our scheme has been effective and has had an effect on equity. The average relative gain of 37.53% allows us to argue that there is learning.

TABLE 3

Descriptive statistical – Total progress (before/after experiment) for all learners (N = 56)

	Mean	**Coefficient of Variation**
Pretest score (in %)	40.23	27.63
Post-test score (in %)	62.65	26.67
Average relative gain (in %)	37.53	76.92

Statistically, the application of Student's t-test for paired samples (Table 4) highlights a significant difference between pretest and post-test (p = .000).

TABLE 4

Inferential analysis - Pretest and post-test comparison

	Test t		
	t	**df**	**P-value**
Pretest VS Post-test	-8,707	55	0.000

Students therefore have a significantly higher level of mastery after handling the digital book. Overall, students obtain a sufficient gain for us to consider a real learning effect. Depending on the taxonomic level, our analysis brings out different results (Table 5).

Taxonomic level of 'knowledge':
Students obtain an average score of 49.68% in the pre-test and 72.11% in the post-test. These results allow us to presuppose a learning effect between the pre-test and the post-test. The CV analysis indicates a decrease from 49.98% for the pre-test to 30.50% for the post-test. This difference allows us to assume that our scheme has been effective and has had an effect on equity. Gains are significant with an average relative gain of 58.30%.

6 The Coefficient of Variation (CV) is the ratio of the standard deviation to the mean x 100.

Taxonomic level of 'understanding':
We observe a small difference between the pre-test and the post-test. On average, students score 23.25% in the pre-test and 24.40% in the post-test. These results allow us to presume a learning effect between the pre-test and the post-test. CV analysis shows a decrease ranging from 135.40% for the pre-test to 112.8% for the post-test. These results indicate a very high variability. This difference indicates a possible effect on equity even though the dispersion of results for this taxonomic level remains very large. The average relative gain of 1.52% shows us that there is no apprenticeship. The students do not obtain a sufficient gain to consider a true learning effect for this taxonomic level.

Taxonomic level of 'analysis':
We observe a small difference between pretest and post-test. On average, students score 56.58% in the pre-test and 61.23% in the post-test. The analysis of the coefficients of variation shows us an increase ranging from 36.57% for the pre-test to 37.83% for the post-test. This increase highlights the fact that our system has not been effective and has not had an effect on equity at this taxonomic level. The average relative gain equal to 10.71% tells us that there is no learning.

TABLE 5

Descriptive statistical – Total progress (before/after experiment) by taxonomic levels

	Mean	Coefficient of Variation
Pretest score for the taxonomic level of "knowledge" (in %)	49.68	49.98
Post-test score for the taxonomic level of "knowledge" (in %)	72.11	30.50
Average relative gain for the taxonomic level of "knowledge" (in %)	58.30	53.94
Pretest score for the taxonomic level of "understanding" (in %)	23.25	135.40
Post-test score for the taxonomic level of "understanding" (in %)	24.40	112.80
Average relative gain for the taxonomic level of "understanding"	1.52	30.63
Pretest score for the taxonomic level of "analysis" (in %)	56.58	36.57
Post-test score for the taxonomic level of "analysis" (in %)	61.23	37.83
Average relative gain for the taxonomic level of "analysis" (in %)	10.71	475.81

A pretest/post-test inferential comparison confirms this observation (Table 6). We observe a significant progression for the 'knowledge' level (p = .000). Nevertheless, we

notice that gains are not significant for 'understanding' level (p = .830) and 'analysis' level (p = .330).

TABLE 6

Inferential analysis - Pretest and post-test comparison by taxonomic levels

	Test t		
Pretest and post-test comparison	**t**	**df**	**P-value**
Taxonomic level of "knowledge"	-11.225	55	0.000
Taxonomic level of "understanding	-0.216	55	0.830
Taxonomic level of "analysis"	-0.979	55	0.333

Is there a relationship between the moment of e-book use and the students' performance?

To answer this question, we compare learners' scores according to the preferred learning modality (e-book before the course vs. e-book after the course). Our aim is to highlight a potential learning effect related to the timing of the availability of the digital book. From a descriptive perspective, we note that the two groups of learners have a fairly similar average with a pre-test score of 42% for the 'pre-course' group and a score of 38.35% for the 'post-course' group (Table 7). Both groups of learners have a higher average score in the post-test than in the pre-test (67.11% for the 'before the course' group and 58.05% 'after the course'). It is noticeable that learners in the 'before the course' group have a higher score than those in the 'after the course' group. Analysis of the average relative earnings shows us that both groups of learners have progressed.

Nevertheless, we note that the use of the e-book before the course favours greater progress than when it is used 'after the course' (respectively, RG = 43.32% *vs.* RG = 31.82%).

TABLE 7

Descriptive statistical – Total progress for each group

	E-book before the course		**E-book after the course**	
	Mean	Coefficient of Variation	**Mean**	Coefficient of Variation
Pretest score (in %)	42.00	26.05	38.35	29.29
Post-test score (in %)	67.11	23.83	58.05	28.57
Average relative gain (in %)	43.32	66.57	31.82	88.05

The application of Student's t-test for matched samples (Table 8) shows that there is no significant difference between pretest and post-test (p = .171).

TABLE 8

Inferential analysis - Comparison by group of pre-, post-test and relative gains

	Test de Levene		Test t		
	F	**P-value**	**t**	**df**	**P-value**
Pre-test	.345	.560	1,065	55	.293
Post-test	.901	.348	1,839	55	.073

These observations allow us to conclude that regardless of when the digital book is made available, it does not influence learning. The way in which digital books are used does not influence learning. The book can therefore be used freely before or after the course depending on the needs of the learners. Depending on the taxonomic level, our analysis brings out different results (Table 9).

Taxonomic level of 'knowledge':
We observe that the subjects of two groups have a fairly similar average score with the pre-test: 34.33% for the 'before the course' group and 31.78% for the 'after the course' group. Table 9 shows that learners in the 'before the course' group have a higher average score in the post-test than learners in the 'after the course' group (respectively, 81.33% *vs.* 62.44%). We find that CVs decrease for both groups at the post-test. These differences suggest that our scheme has been effective and has had an effect on equity. The observation of average relative gains allows us to assess scores above the 30% threshold raised by D'Hainaut (1975). Both groups seem to progress to the taxonomic level 'knowledge'.

Taxonomic level of "understanding":
Learners in the "pre-course" group did not progress between the pre-test and post-test. On the other hand, those in the "after the course" group made significant progress between the pre-test and post-test (respectively, 26.19% vs. 28.57%). The "after course" group scored higher than the "before course" group. The analysis of the CVs shows a significant heterogeneity which suggests that the scheme has not been effective and has not had an effect on equity. The analysis of average relative gains indicates that there was no learning for any group.

Taxonomic level of "analysis":
We observe that the subjects of two groups have different average scores with the pre-

test: 60.50% for the "before the course" group and 52.33% for the "after the course" group. Despite different scores in the pre-test, we observe that the learners in the "after the course" group have a score in the post-test that is quite close to that of the subjects in the "before the course" group (respectively, 61.11% vs. 61.33%). The analysis of average relative gains indicates that there was no learning for any group.

TABLE 9

Descriptive statistical – Total regression for each group according to taxonomic levels

		E-book before the course		**E-book after the course**	
Taxonomic levels		**Mean**	Coefficient of Variation	**Mean**	Coefficient of Variation
Knowledge	Pre-test score (in %)	34.33	46.60	31.78	54.54
	Post-test score (in %)	81.33	22.81	62.44	34.34
	Average relative gain (in %)	71.54	279.91	55.85	199.32
Understanding	Pre-test score (in %)	20.45	144.32	26.19	129.7
	Post-test score (in %)	20.45	144.32	28.57	88.73
	Average relative gain (in %)	0	0	3.23	436.84
Analysis	Pre-test score (in %)	60.61	31.23	52.38	41.83
	Post-test score (in %)	61.33	33.93	61.11	42.54
	Average relative gain (in %)	3.35	60.23	17.86	59.65

If there is no difference of gains for "understanding" ($p = .418$) and "analysis" ($p = .965$) level, we can observe that students who use the e-book before the course have a significant progression for mastering of basic knowledge ($p = .004$) (Table 10). The student's performance is higher when they discover the digital book before the course than afterwards. In our case, the use of the digital book before the course has an effect on the level of taxonomic "knowledge".

TABLE 10

Inferential analysis - Comparison by group of pre-, post-test and relative gains according to taxonomic levels

		Levene test		Test t		
		F	**P-value**	**t**	**df**	**P-value**
Knowledge	Pre-test	.038	.847	.510	55	.612
	Post-test	.842	.364	3.084	55	.004
	ANCOVA	**Average Squares**		**df**	**F**	**Sig**
		27.588		1	9.232	.004
		F	**P-value**	**t**	**df**	**P-value**
Understanding	Pre-test	.873	.355	-.592	55	.557
	Post-test	.288	.595	-.965	55	.340
	ANCOVA	**Average Squares**		**df**	**F**	**Sig**
		.192		1	.671	.418
		F	**P-value**	**t**	**df**	**P-value**
Analysis	Pre-test	.060	.808	1.319	55	.194
	Post-test	1.548	.221	.035	55	.972
	ANCOVA	**Average Squares**		**df**	**F**	**Sig**
		.004		1	.002	.965

Is there a relationship between the moment of e-book use and modalities of use of it?

The study's originality is our collect of information from an analysis of traces (learning analytics) by way of a screen-casting process to evaluate real uses of students during their reading. To answer our third question, we studied the modalities of use of digital books by university students to observe if there are differences depending on the moment of reading (Table 11).

Descriptively, table 11 shows that learners using the e-book before the course performed more actions than those reading it after the course (respectively, 71.29% vs. 65.27%). On the other hand, learners in the 'after class' group spent more time browsing the e-book than learners in the other group (respectively, 78.28 min vs. 73.11 min). Concerning the actions carried out, we observe that learners who read the e-book before the course consult more resources such as bibliographical references, slide shows, video and audio than those in the group who discover the e-book after the course (respectively: 75.67% vs. 74.67%; 106.75% vs. 101.25%; 94.18% vs. 93%). It is also the learners who use the book

before the course also do more exercises, read instructions, answer questions, check and correct themselves more than those in the other group (respectively: 142.14% vs 105.43%; 103.85% vs 102.71%; 112.42% vs 102.92 and 38.11% vs 35.54%).

TABLE 11

Descriptive statistics - Actions carried out in the field of digital books

		Terms of use of the digital book			
		E-book before the course		**E-book after the course**	
		Mean	Coefficient of Variation	**Mean**	Coefficient of Variation
General resources	Total actions carried out (in %)	71.29	9.25	65.27	24.20
	Reading of the written word (in %)	107.29	13.81	97.37	23.94
	Reading time (in min and in %)	73.11	9.91	78.28	27.40
Resources of an informative nature	Use of the glossary (in %)	2.77	133.11	6.22	157.34
	Additional information (in %)	38.82	58.78	45.00	51.71
	Internet links (in %)	7.00	250.00	33.50	356.70
	Bibliographical references (in %)	75.67	49.34	74.67	67.54
Explanatory resources	Slideshow playback (in %)	106.75	14.75	101.25	12.34
	Enlargement of slide shows (in %)	106.75	14.75	107.25	26.80
	Reading of diagrams (in %)	86.50	50.86	95.00	28.42
	Enlargement of diagrams (in %)	84.00	53.32	95.00	23.68
Multimedia resources	Listening to audio (%)	94.18	15.06	93.09	23.53
	Audio playback (in %)	4.54	192.60	1.30	335.66
	Video playback (%)	95.50	22.51	88.00	30.68
	Revision of videos (in %)	2.25	473.33	16.50	221.21
	Enlargement of videos (in %)	50.00	53.45	54.50	91.28

TABLE 11

		Terms of use of the digital book			
		E-book before the course		E-book after the course	
		Mean	Coefficient of Variation	**Mean**	Coefficient of Variation
Resources of a formative nature	Carrying out the exercises (in %)	142.14	37.14	105.43	12.46
	Reading of the setpoint (in %)	110.43	24.96	112.28	42.24
	Response to questions (in %)	103.85	17,93	102.71	13.39
	Response verification (%)	112.42	48.60	102.92	20.18
	Correction of the answer (in %)	38.11	49.13	35.54	49.13

Conversely, students who read the e-book after the course tend to consult the glossary, additional information and Internet links more than others (respectively: 2.77% vs. 6.22%; 38.82% vs. 45.00 and 7.00% vs. 33.50%). These same learners also invest more in educational media by enlarging slideshows, reading and enlarging graphics than those in the 'pre-course' group (respectively: 106.75% vs. 107.25%; 86.50% vs. 95.00% and 84.00% vs. 95.00%).

The application of Student's t-test for matched samples (Table 12) shows that there are significant differences depending on the modalities of use of e-book. Students who discover the e-book before the course do more exercises on it than when they are given the tool after the course (p = .004). Conversely, students who consult the e-book after the course tend to enlarge the diagrams more than those who consulted before the course (p = .001).

TABLE 12

Descriptive statistics - Actions carried out in the field of digital books

		Terms of use of the digital book				
		Test de Levene		Test T		
		F	**P-value**	**t**	**df**	**P-value**
General resources	Total actions carried out (in %)	.927	.341	1.621	55	.113
	Reading of the written word (in %)	2.477	.123	-1.150	55	.257
	Reading time	.203	.655	1.629	55	.111

TABLE 12

		Terms of use of the digital book				
		Test de Levene		Test T		
		F	P-value	t	df	P-value
Resources of an informative nature	Use of the glossary (in %)	9.940	.003	-1.542	55	.131
	Additional information (in %)	.001	.976	-.879	55	.384
	Internet links (in %)	1.123	.296	.086	55	.932
	Bibliographical references (in %)	3.425	.071	-1.028	55	.310
Explanatory resources	Slideshow playback (in %)	3.132	.084	1.295	55	.132
	Enlargement of slide shows (in %)	9.001	.978	-.044	55	.001
	Reading of diagrams (in %)	3.762	.059	-.791	55	.762
	Enlargement of diagrams (in %)	7.729	.008	-.985	55	.331
Multimedia resources	Listening to audio (%)	.048	0,828	.204	55	.839
	Audio playback (in %)	6.345	.016	1.528	55	.134
	Video playback (%)	1.617	.211	.996	55	.325
	Revision of videos (in %)	12.942	.001	-1.772	55	.084
	Enlargement of videos (in %)	.765	.387	-.393	55	.696
Resources of a formative nature	Carrying out the exercise (in %)	12.598	.001	3.098	55	.004
	Reading of the setpoint (in %)	.036	.851	-.158	55	.876
	Response to questions (in %)	.222	.640	.234	55	.816
	Response verification (%)	1.565	.218	1.352	55	.184
	Correction of the answer (in %)	1.998	.165	.572	55	.570

Is there a relationship between students' discovery process of e-book, their initial characteristics and their learning gains?

The last question concerns the relationship between students' modalities of use of e-book and their mastery at the end of learning. To answer this question concerning the identification of actions related to the reading of digital books that may influence learner performance, we used a backward elimination regression analysis technique. This statistical technique makes it possible to relate a predicted variable – performance – to a set of predictive variables. This choice stems from the fact that 'multiple regression models are mathematical models that make it possible to study the association between exploratory factors and a variable to be explained, with a view to description and/or prediction' (Gillaizeau & Grabar, 2011, p. 360). This statistical method makes it possible to

highlight the supposed relations between a dependent variable and several independent variables (Foucart, 2006). This method is particularly effective in highlighting a model that gives the highest degree of prediction while discarding the least relevant variables (Boumazguida, 2020).

To explain relative gains of students for different taxonomic levels, we will integrate into our regression analysis variables related to the process of reading the e-book. We identify two explanatory models for the development of 'understanding' and 'analysis' skills.

For the 'understanding' level (Table 13), the model generated shows that the significant variables are reading the slideshows (.032), enlarging the slideshows (.028), answering the questions (.018) and the pre-test score (.053). In this model we find that the power of prediction estimated from the adjusted R^2 is .211. This means that the independent variable contributes only 21.1% of the variation in performance. The second piece of information to be taken into account in this model comes from the significance level of F (43.190). This value allows us to affirm that there is a significant linear relationship between performance and the five variables of the model. The more students consult additional information (β = .253), enlarge slide shows (β = .653) and answer questions (β = .361), the better they perform in terms of comprehension. The model also tells us that students with a low starting level make the most progress in comprehension (β = -.284). Counter-intuitively, we finally observe that fewer students read slide shows (β = -.650) the better the results.

TABLE 13

Regression analysis of process variables - Learning gains in "understanding"

	Learning gains in understanding
R	.554
R^2	.307
Adjusted R^2	.211
F	43.190
Predictor n°1	More information
β	.253
Sig.	.087
Predictor n°2	Slide show lecture
β	-.650
Sig.	.032
Predictor n°3	Enlargement of slideshows

TABLE 13

Learning gains in understanding	
β	.653
Sig.	.028
Predictor n°4	Answers to questions
β	.361
Sig.	.018
Predictor n°5	Pre-test score in "understanding"
β	-.279
Sig.	.053

For the 'analysis' level (Table 14), students whose consult glossary (β = .290) and verify their mistakes by the feedbacks reading (β = .645) have the best mastery of the 'analysis' level. Students whose have a low level in the 'analysis' level are they whose progress the most in 'analysis' (β = -.344). Models with these 2 interacting variables contribute only to explain 40% of the variation in this performance (adjusted R^2 of the model = .408). Logically, comparison between the 2 models highlights that learners whose use of e-book' resources understand his content better.

TABLE 14

Regression analysis of process variables - Learning gains in "analysis"

Learning gains in analysis	
R	.552
R^2	.305
Adjusted R^2	.250
F	44.405
Predictor n°1	Consultation of the glossary
β	.300
Sig.	.042
Predictor n°2	Verification of exercises
β	.353
Sig.	.016
Predictor n°3	Pretest score in "analysis"
β	-.344
Sig.	.018

Discussion

This research shows that students' discovery of e-books before the course has an impact on their progress. These results are consistent with others that have found that the performance of students who use e-books before the course is higher than those who use it after the course (Papadopoulos & Roman, 2010; Stirling & Birt, 2013). More specifically, we observe that the digital book has an impact, in the medium term, on the progress of students regarding the level of 'knowledge' of Bloom's taxonomy. We do not expect any progress for the other two levels.

To show if there is a relationship between the moment of e-book use and modalities of use of it, we use a videography analysis system of learners' actions when they are reading it. Students who read the digital book before the course don't do more actions (audio listening, slide/video reading…) than others. Exception for achievement of exercise when they use it after the course. We suppose that there is some form of enthusiasm for exercises related to the fact that learners want to verify their understanding of the contents. This is reassuring because, as Thobois Jacob (2018), quoting Dunlosky et al. (2013), explains, 'practice tests are probably one of the most effective and useful learning strategies because they benefit learners of all ages and enhance performance in a variety of educational contexts' (p. 5). These results are also congruent with Kim et al. (2014) whose explain that quizzes stimulate learners to engage in learning activity. According to Hattie (2009), questioning learners would be the pedagogical approach that would have the greatest effect on learning. We hypothesise that the use of the exercises allowed learners using the digital book before the course to have better results at the taxonomic level of 'knowledge'.

Furthermore, students who successfully complete their exercises on the first attempt look to have integrated content that has been proposed. When they do not, they have to repeat it. So, in this context, repetition looks to be a synonym for failure. However, watch several times the video can be explained by the fact that they already have the knowledge of contents that give them the possibility to devote more time to watch video. Students don't hesitate to watch video, especially when they don't understand something.

This research also shows that the time spent reading an e-book is more important when students discover it before the course (result not significant). These results are opposed by Lucke (2014) who describes this pedagogical method as one which students can learn in their own timing. As Marton and Säljö (1976) explain, working autonomously, in a self-regulated way (Cosnefroy, 2011), is not always easy for students who are not accustomed to this 'freedom' and it traps students who often need to be steered by their teacher to use them.

Finally, our study that wanted to show a relationship between the students' discovery process of e-book, their initial characteristics and their learning gains

highlights some potential factors for success: glossary, expanding slideshows, and verifying answers.

For the 'analysis' level, our results are congruent with Hattie & Timperley (2007) whose bring out the positive effects of feedback. Indeed, as Thobois Jacob (2018) explains, quoting Roediger and Karpicke (2006), students who have the opportunity to test their knowledge immediately (testing effect) after learning, as in the case of the e-book, obtain better results in the final assessment than those who have merely revised the course. According to this author, the 'phenomenon of the testing effect is explained by the fact that […] the immediate test makes it possible to actively recall content, whereas revision is a passive activity: cognitive engagement is therefore stronger during testing activity than during revision, which consists of rereading the content to be learned several times' (Thobois Jacob, 2018, p. 112). Although the results of our analyses are interesting for the teacher-researcher, we note some limitations. The absence of a control group seems to be a limitation resulting from our experiment, as it is the evaluation of such a group that would have given an opportunity to advance a real progression, linked to our system, among the learners. The small size and nature of our sample does not allow us to generalise our different conclusions to a larger population. Furthermore, it would be desirable to reproduce our research over a longer period of time so that learners can really experience the reverse classroom experience and not become isolated in a single experience. This would eliminate any risk of novelty bias that might arise in this type of experimentation confronting an audience with a new technology. In addition, we recommend a greater number of subjects from different backgrounds in order to attest to and generalise the different points developed through our study.

Finally, among the possible perspectives, we believe that this type of techno-pedagogical tool is likely to bring added value in terms of university pedagogy. This is why, in all modesty, we hope that the use of digital books will arouse real enthusiasm among supervisory staff so that they can be offered on a more recurrent basis to university students. Finally, in line with the work of Temperman (2013) and Boumazguida (2020), we suggest the development of automatic tracking systems for the automated collection of learning traces.

In conclusion, we believe that this type of techno-pedagogical tool is likely to bring added value in terms of university pedagogy. The use of the digital book before the course would make it possible to empty classrooms so that students can learn (at a distance) at their own pace and take advantage of face-to-face teaching moments to ask their teachers in-depth questions. The digital book could help students to succeed because it allows them to learn at their own pace.

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