sustainability

MDPI

Article

Ontology-Enhanced Educational Annotation Activities

Joaquín Gayoso-Cabada [1], María Goicoechea-de-Jorge [2], Mercedes Gómez-Albarrán [1], Amelia Sanz-Cabrerizo [2], Antonio Sarasa-Cabezuelo [1] and José-Luis Sierra [1,*]

[1] Facultad de Informática, Universidad Complutense de Madrid, 28040 Madrid, Spain
[2] Facultad de Filología, Universidad Complutense de Madrid, 28040 Madrid, Spain
* Correspondence: jlsierra@ucm.es; Tel.: +34-91-3947548

Received: 2 July 2019; Accepted: 12 August 2019; Published: 17 August 2019

Abstract: Information and communications technology and technology-enhanced learning have unquestionably transformed traditional teaching–learning processes and are positioned as key factors to promote quality education, one of the basic sustainable development goals of the 2030 agenda. Document annotation, which was traditionally carried out with pencil and paper and currently benefits from digital document annotation tools, is a representative example of this transformation. Using document annotation tools, students can enrich the documents with annotations that highlight the most relevant aspects of these documents. As the conceptual complexity of the learning domain increases, the annotation of the documents may require comprehensive domain knowledge and an expert analysis capability that students usually lack. Consequently, a proliferation of irrelevant, incorrect, and/or poorly decontextualized annotations may appear, while other relevant aspects are completely ignored by the students. The main hypothesis proposed by this paper is that the use of a guiding annotation ontology in the annotation activities is a keystone aspect to alleviate these shortcomings. Consequently, comprehension is improved, exhaustive content analysis is promoted, and meta-reflective thinking is developed. To test this hypothesis, we describe our own annotation tool, *@note*, which fully implements this ontology-enhanced annotation paradigm, and we provide experimental evidence about how *@note* can improve academic performance via a pilot study concerning critical literary annotation.

Keywords: educational annotation tool; ontology; critical literary annotation; cooperative/collaborative learning; interactive learning environments

1. Introduction

The role of information and communication technology (ICT) and technology-enhanced learning (TEL) to achieve quality education, one of the 17 sustainable development goals (SDGs) raised by the United Nations General Assembly 2030 Agenda [1] (SDG 4) aimed to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" has been widely acknowledged [2,3]. In addition to offering students who cannot attend classes access to education, ICT provides more agile access to knowledge than more traditional approaches, and TEL has enormous potential to guarantee universal access to knowledge and education, transforming the teaching–learning processes and adapting them to each specific educational scenario and to each individual student [4].

A representative example of the transformative role of TEL in education is content annotation. Annotation activities, which have great value in the learning process and that were traditionally carried out using pencil and paper, have taken advantage in recent years of digital document annotation tools. These tools enable learning activities based on the addition of marks and comments in the contents of the documents, which enable highlighting, complementing, and enriching some of their aspects. The

use of digital annotations for an educational purpose has been extensively analyzed in the literature. For this purpose:

- One of the relevant concerns regarding educational use of digital annotations is to compare these digital annotations with respect to conventional, handwritten, ones. A representative work in this line is that reported in [5], where two experiments are presented that try to analyze the differences between the annotations made on paper and those made online by students. These experiments focused on aspects such as types of annotations, the purpose of annotations, the quality of the annotations, the difficulties creating and using them (search strategies, time spent searching), etc. The results of the experience showed that the annotations on paper were longer and richer from the conceptual point of view than those made online, although the latter were more oriented towards sharing, commenting on, or recovering the annotated resource. In a similar way, [6,7] showed that students using a digital annotation tool outperformed those who annotated the text using paper and pencil.
- Another relevant concern is analyzing how digital annotations can contribute to improving reading comprehension. For instance, in [8], two groups of students who read the same text with annotations and without annotations respectively were considered and subsequently evaluated regarding the content. The result showed that the students who had read the annotated text performed better. In [9] an experiment was set up in which readers in a group were exposed to all the annotations in the text, while readers in another group were exposed to high-level annotations only. Reading comprehension was tested, and the results showed that the readers who had used high-level annotations achieved much better reading comprehension than those who were exposed to all the annotations.
- In addition to supporting reading, the true educational potential of digital annotation tools is achieved when students actively participate in the annotation process. In this regard, in [10] an experiment was conducted in which a group of students read a text, while another group read and annotated it. The students who annotated the text achieved better results and were more motivated. In [11] an experiment was set up in which students in one group annotated a text individually, while students in another group worked in pairs, with one acting as an annotator and the other acting as a reviewer of the annotations made by the first one. The results showed that when students work in pairs to annotate the same document, redundancy is reduced, and topics addressed are discussed in greater depth.
- Finally, another relevant topic is the enabling of collaborative annotation activities, in which students collaborate on the digital annotations of texts. In [11], a study focusing on multimedia annotations of web-based content made it apparent how individual annotation can be outperformed by collaborative annotation. In [12] several experiments in the context of an English course were described that, in addition to focusing on analyzing the effects of annotation systems on reading comprehension, also focused on the analysis of critical thinking and metacognitive competences. For this purpose, a group of students annotated and read the texts proposed individually, while another group carried out the activity in a collaborative way. Students who worked on the texts in a collaborative way improved their metacognitive competences and their reading comprehension. However, there was no difference in critical thinking. A similar study was conducted in [13], in which the results showed that, although the collaborative annotation strategy negatively affected the students' initial performance, it had clearly positive effects on the tests taken one month after the experience compared to those of the students who followed a non-collaborative annotation strategy. In [14,15], two experiments based on collaborative annotation of online documents carried out by pairs of students are described. The highest-quality annotations were made by students who were more motivated to use the tool. They also achieved the highest grades. In [16] the effect of annotations in collaborative environments was investigated. For this purpose, the performance of students using a conventional discussion board system was compared to that of students using a collaborative annotation tool. The results showed that the use of an annotation

system can increase learning achievement in collaborative learning environments. In [17] a collaborative annotation system was compared to a recommender-supported system. Although both approaches outperformed individual annotation, no statistical differences were observed between them.

However, as the conceptual complexity of the learning domains increases, annotation tasks require a comprehensive knowledge of the domain [18]. Consequently, annotation activities are difficult for students who frequently highlight irrelevant aspects of the content in some of their annotations and bypass other aspects of utmost importance to satisfy a certain annotation objective. As a result, learning outcomes are suboptimal. Thus, guidance is required to provide a better learning experience. Unfortunately, most of the available annotation tools focus on providing appealing user experiences (e.g., enrichment by multimedia contents) or supporting collaborative annotation by groups of students more than providing adequate guidance for achieving successful educational experiences [19].

In this paper, our main research hypothesis is that the use of suitable *annotation ontologies* can provide students with the necessary guidance during the annotation of documents in complex learning domains. Instructors provide annotation ontologies that capture their particular conceptual frames and annotation goals. Students benefit from a document annotation paradigm that properly combines semantic and free-text annotation approaches. Thus, students can express the various aspects of the analyzed documents in natural language while using a guiding ontology to properly classify their annotations. This explicit classification of annotations promotes meta-reflective thinking since students are forced to reflect on the purpose of every annotation in the context of the activity. Our annotation paradigm has been put into practice in the *@note* annotation tool, whose initial conception and some subsequent evolutions are described in [20–22].

The content of this paper is organized as follows. Section 2 discusses related work. Section 3 briefly describes the methodology used to study the effect of annotation ontologies in the annotation process, introducing *@note* and describing a pilot study concerning *critical literary annotation*. Section 4 describes the results obtained in the pilot. Section 5 provides a discussion of these results. Section 6 concludes the paper and presents future work.

2. Related Work

Unlike other works related to annotation tools, which emphasize the aforementioned aspects of comparing digital versus handwritten annotations, analyzing how digital annotations impact the reading process or how readers can become actively involved in the text annotation process, paying special attention to collaborative annotation of texts by groups of annotators, in this paper we mainly focus on the mechanisms offered by the annotation tools for classifying annotations. For this purpose, we identified five main approaches concerning the classification of annotations (see [23] for a more detailed account):

- *Lack of mechanisms for classifying annotations*. This approach groups tools that prioritize other aspects instead of organizing annotations, such as sophisticated ways of interacting with the documents.
- *Predefined annotation modes*. Tools that follow this approach provide different ways of annotating a document (underlining or highlighting fragments and adding comments), which induce an implicit categorization of the annotations.
- *Pre-established semantic categories*. This approach is adopted by tools that introduce a predefined set of semantic tags to classify annotations.
- *Folksonomies*. This approach is based on the classification of annotations by mean of tags that are created by the users to conform a folksonomy. Previously created tags (by the user or other participants in the annotation activity) can be employed or new tags that are better suited to particular classification needs can be created.

- *Ontologies*. Tools that adhere to this approach enable loading specific ontologies for each annotation activity. Students can use these ontologies to make the semantics of annotations explicit (e.g., by associating one or more concepts in the ontologies to the annotations).

Table 1 provides representative examples of tools in each of the categories. Concerning the guidance of students during the annotation process in complex domains:

- Tools that lack mechanisms for classifying annotations and tools based on predefined annotation modes imitate conventional paper-and-pencil-based annotation mechanisms, perhaps modulated with a greater repertoire of presentation styles. Therefore, they do not provide any mechanism to support students' guidance.
- Concerning tools that are based on predefined repertories of semantic categories, although the lists of tags provided by these repertories allow annotations to be classified according to certain semantic criteria, their pre-established nature produces generic classification systems, which typically consist of general purpose and reduced sets of universal categories (4 in *PAMS 2.0* or in *MyNote*, 7 in *CRAS-RAID*, 9 in *Tafannote* or in *MADCOW*, etc.), which may not fit the specific characteristics of every annotation activity.
- Folksonomy-based tools enable lists of semantic tags that are specifically adapted to each annotation activity. However, most of these tools delegate the collaborative design of these vocabularies of tags to the students. For instructors, this practice does not guarantee that the resulting folksonomies adequately capture the objectives of the annotation activity, because it requires a considerable amount of expert knowledge that students lack. Although some of the folksonomy-based tools (e.g., *annotation studio*) also provide support for tag repertories provided by instructors, folksonomies lack structure beyond the provided by simple tag lists, which can be inconvenient for in-depth annotation.
- Ontology-based tools provide appropriate vehicles (ontologies) for capturing specific knowledge about annotation activities, which enables the adaptation of the tools to the semantic particularities of each activity and provide a high degree of contextualization in this activity. In addition, the structural richness of ontologies solves the problems of lack of structure of plain lists of semantic tags.

From these annotation classification approaches, the approaches that are based on explicit ontologies appeared as the most appropriate ones to guide students. However, the tools in this category have some shortcomings, which hinder their applicability:

- The complexity of the ontology definition by instructors must be carefully considered. Of the tools that were analyzed, only *Loomp* addresses this aspect; it proposes a two-level organization scheme that is based on *vocabularies* that cluster atomic concepts. This approach is too simple for conceptual organization purposes. The other tools adopt standard semantic web technologies (like RDFS—Resource Description Framework Schema, or OWL—Web Ontology Language) and do not introduce mechanisms to help instructors provide the ontologies.
- All ontology-based tools that were analyzed differentiate between semantic annotations and other types of annotations. This fact is evident, for example, in *DLNotes*, which explicitly distinguishes between semantic annotations and free-text annotations. The other tools focus on the process of semantic annotation, which is understood as semantic tagging of document fragments. From a detailed annotation perspective, providing textual content to annotations in free-text format is essential to reflect the particular and subjective reading of the content by the student.

Table 1. Examples of tools categorized according to their annotation classification approaches.

Annotation Classification Approach	Examples of Tools
Absence of classification mechanisms	*Digital Reading Desk* [24] *Livenotes* [25] *WriteOn* [26] *PaperCP* [27] *u-Annotate* [28]
Predefined annotation modes	*Adobe Reader* (acrobat.adobe.com) *PDF Annotator* (www.pdfannotator.com) *Diigo*'s (www.diigo.com) annotation tool [29] *Amaya*'s annotation tool [30], *Anozilla* (annozilla.mozdev.org) *CASE* [31] *CON2ANNO* [32] *Online annotation system* [33] *VPen* [11] *IIAF* [34]
Pre-established semantic categories	*eLAWS* and *Annoty* [35] *Highlight* [36] *PAMS* 2.0 [16] *MyNote* [37] *Tafannote* [38] *WCRAS-TQAFM* [9] *CRAS-RAID* [6] *UCAT* [39] *MADCOW* [40]
Folksonomies	*HyLighter* (www.hylighter.com) [41] *Hypothe.sis* (web.hypothes.is) [42,43] *annotation studio* [44] *A.nnotate* [45,46] *Note-taking* [47] *OATS* [48,49] *SpreadCrumbs* [5,50] *Tsaap-Notes* [51]
Ontologies	*Loomp* [52,53] *DLNotes* [54] *MemoNote* [55,56] *WebAnnot* [57] *New-WebAnnot* [58]

3. Materials and Methods

To study how the emphasis on annotation ontologies can enhance educational annotation activities in complex domains, we adopted a methodology that is grounded on *design-based research methods* [59]:

- Following the guidelines of design-based research methods, to address the aforementioned shortcomings of ontology-based annotation tools we designed and developed our own annotation tool, *@note*, which fully implement our annotation paradigm. This tool is detailed in Section 3.1.
- To assess the educational utility of *@note*, we undertook a pilot experiment concerning a learning domain that requires a large amount of domain knowledge and skilled annotation capabilities: *critical literary annotation*. Concerning the quantitative analysis method in this experiment, we opted for a *within-subject design* approach [60] since it fits reduced groups of students, which typically arise in advanced university-level literature courses. The pilot design is detailed in Section 3.2.

3.1. @note Annotation Tool

The two main distinctive features of *@note* and existing ontology-based annotation tools are:

- *@note* places a strong emphasis on integrating free-text and semantic approaches in a single annotation paradigm.
- *@note* is equipped with user-friendly ontology-edition mechanisms suitable for end users with no specific background in computer science or knowledge engineering, which allows instructors to design reasonably complex ontologies. These ontologies are based on taxonomic arrangements of concepts, and therefore overcome the simplicity of other tools that pay attention to this aspect (e.g., the two-level organizations of vocabularies in *Loomp*).

The central construct of *@note* is that of *annotation activity*. These activities are defined by instructors and they can be carried out by students. Thus, the tool offers instructors a complete set of features to design annotation activities (Section 3.1.1). Among these features, the most relevant ones are those oriented to the provision of annotation ontologies (Section 3.1.2). Once the annotation activity has been properly customized, *@note* provides students with an interactive environment in which to make annotations (Section 3.1.3) and instructors with several features for assessing the annotation activities (Section 3.1.4).

3.1.1. Annotation Activities

Annotation activities in *@note* are oriented to accomplish specific annotation objectives (what aspects should be annotated, and for what purpose). *@note* facilitates instructors in conceiving and refining these activities by providing them with user-friendly editing tools for configuring each of these aspects. Each annotation activity comprises the following aspects:

- The *document to annotate*. When designing an annotation activity, the instructor must choose the document to be annotated by the students. In the current version of *@note*, these documents can be obtained from the collection of Google digitized books (books.google.com) or by directly loading documents into the tool (Figure 1a).
- The *annotation group*. This set of students will be in charge of performing the activity (Figure 1b).
- The *annotation ontology*. This ontology will guide the students throughout the annotation process (Figure 1c).

Figure 1. Snapshots concerning the creation of an annotation activity in *@note* for the *literary theory and text analysis* discipline: (**a**) the document to be annotated uploaded in *@note*; (**b**) the annotation group built with the group creation tool (usernames of students intentionally hidden); (**c**) an excerpt of the annotation ontology.

The most critical aspect is the one that is concerned with the annotation ontologies. This critical aspect is discussed in the next paragraph.

3.1.2. Annotation Ontologies

Annotation ontologies enable students to explicitly classify their annotations. An annotation ontology will depend on the annotation objectives of the activity. The instructor will be able to focus on different concepts based on the aspects of the content that he or she wishes to focus on during the annotation process. Depending on the nature and specificity of the activity, the instructor will provide an ontology that is oriented to the activity or he/she will profit from reusing or adapting an existing ontology. To reduce the workload of defining the annotation ontologies, *@note* enables instructors to control the visibility of their ontologies (*private* or *public*), participate in the collaborative edition of public ontologies with their colleagues, and reuse existing ontologies for new annotation activities.

@note enables annotation ontologies to be defined as taxonomical arrangements of concepts. Thus, *@note* adopts a compromise solution between the simplicity of the two-level organization of vocabularies in *Loomp* and the complexity of the unrestricted ontology definition formalism (as supported by the other ontology-oriented tools). The aim was to provide an approach that is sufficiently flexible for annotation and sufficiently friendly to facilitate the definition of ontologies for instructors without expertise in computer science or knowledge engineering. This solution enables instructors to define substantially complex ontologies using the user-friendly *@note* edition features. Figure 1c shows an excerpt of an ontology for a generic theory of *critical literary analysis* [61]. *@note* annotation ontologies include two kinds of concepts:

- *Intermediate* concepts can be refined in terms of other simpler sub-concepts. For instance, in Figure 1c, concepts such as *Analysis*, *Structure*, *Structure_type* or *Criticism* are intermediate concepts, and *Structure_type*, *Plot*, and *Setting* are direct sub-concepts of *Structure*.
- *Final concepts* are concepts that the students can use to classify annotations. These concepts correspond to the taxonomy leaves. In Figure 1c, *Narration*, *Use_Of_frames, Plot*, *Setting*, *Bibliographical*, *Psychological*, and *Cultural* are final concepts that students can use to classify their annotations.

This hierarchical organization of concepts facilitates, on the one hand, the search for the most appropriate final concepts for each annotation during the annotation of the document and, on the other hand, the filtering of the annotations during the assessment of the annotation activity, because it is possible to filter by both final concepts and intermediate concepts (in this case, the result will be all the annotations catalogued by the final concepts that descend from the chosen one).

As shown by Figure 1c, in *@note*, the hierarchical relationship between concepts is expressed by brackets. This representation is useful to have a complete visual snapshot of the ontology and during text annotation and activity assessment. It is also useful for editing the ontology, as the editor lets instructors rename, delete, and reorganize the hierarchical arrangement of concepts, which is an essential feature to support the continuous improvement of the annotation activities.

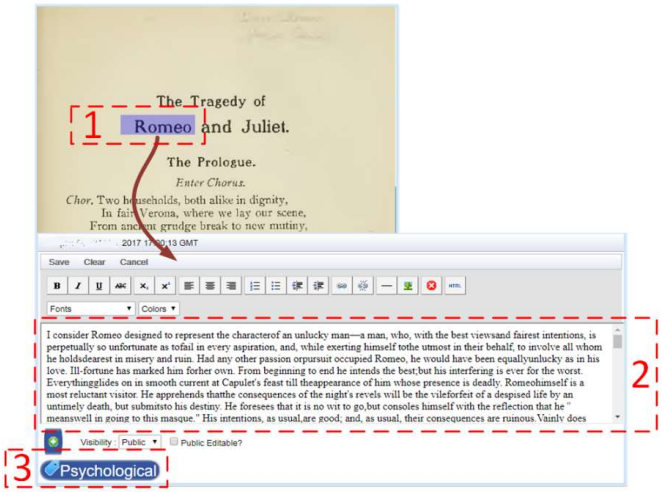
@note also enables instructors to specify intermediate concepts which allows students to scope their own final concepts. This feature leaves the ontology open to the suggestions of the students. As a result, *@note* accommodates folksonomy-based approaches to content annotation in a controlled manner. From the instructor perspective, this feature makes it possible to diagnose possible disadvantages of the ontology and possible problems in the assimilation of the underlying theory by students.

3.1.3. Making Annotations

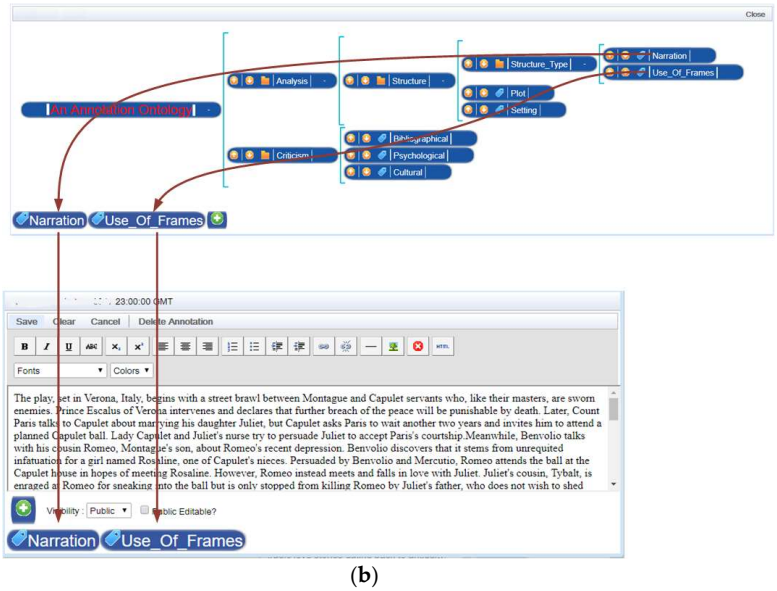
Once the annotation activity has been configured by instructors, *@note* offers the students an environment in which to perform the annotation of the document. They select parts of the document and associate the content of their annotations with these fragments. In accordance with the previously

mentioned considerations, they also associate one or more ontology concepts with each annotation to classify it. Consequently, an annotation in *@note* consists of (Figure 2a):

- An *anchor*. The *anchor* is an area of the digital document associated with the activity, which students can delimit with a mouse.
- A *content*. The *content* is an unconstrained description provided by the students. In *@note*, annotation contents can contain text and substantially richer multimedia content (images, video, and audio), links to other resources, and any type of HTML5-compliant information.
- A *classification*. The *classification* is a set of final concepts taken from the annotation ontology. Each annotation must have at least one final concept associated with it. To perform the classification of their annotations, students use the representation of the annotation ontology and select concepts that they consider to be relevant (Figure 2b). The hierarchical organization of concepts and the associated bracketed representation facilitates this task, helping students to identify the most suitable concepts and offering a complete visual snapshot of the ontology.



(**a**)



(**b**)

Figure 2. (**a**) Example of a student' annotation in *@note* (1: anchor, 2: content, and 3: classification); (**b**) semantic classification of an annotation in *@note*.

Thus, free-text and semantic annotation approaches are consistently combined in *@note*. Each annotation must be classified according to the annotation ontology. Likewise, transversal notes, which simultaneously address several aspects, may be semantically tagged with more than one final concept in this ontology.

3.1.4. Assessment of Annotation Activities

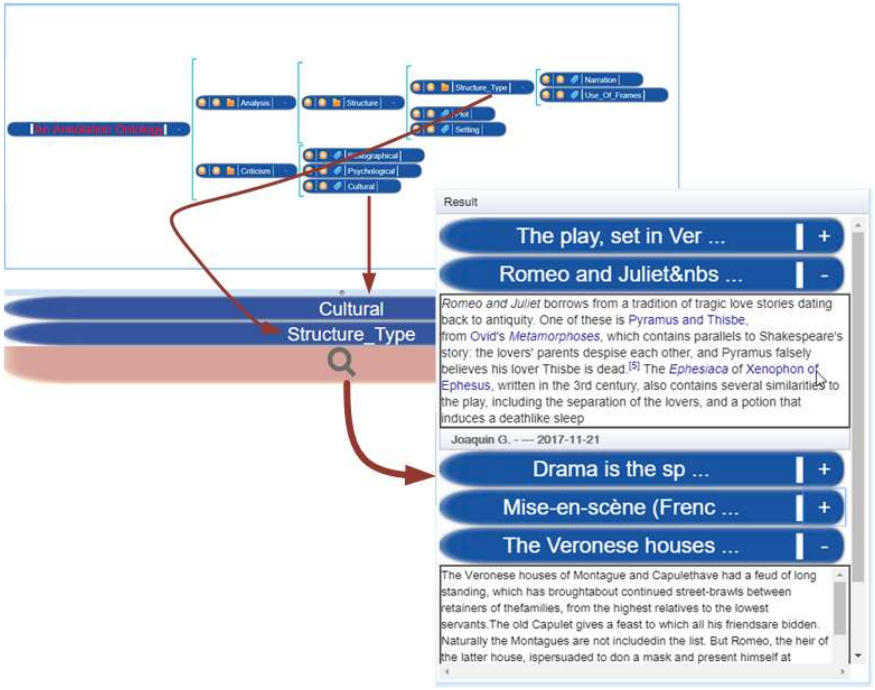
To support the assessment of annotation activities, *@note* offers instructors two basic mechanisms for retrieving student annotations based on their semantic classifications:

- The instructor can select all annotations that are tagged with a set of concepts, either intermediate concepts or final concepts. The annotations that are selected will be the annotations that are tagged with the final concepts chosen by the instructor and at least a final sub-concept of each intermediate concept chosen by the instructor. Figure 3a illustrates this mechanism: the annotations that are selected will be the annotations that are tagged as *Cultural* and a final sub-concept of *Structure_Type* (i.e., by *Narration* or *Use_Of_Frames*).
- The instructor can also use a more sophisticated search engine based on arbitrary Boolean queries in conjunctive normal form. Concepts can be asserted or denied and grouped together to express conjunctions. Each of these conjunctions is referred to as a *criterion*. Final queries are formulated by disjunctions of criteria. For example, Figure 3b illustrates the edition and application of a query with two criteria: the first criterion is named *Narrative* and enables the selection of annotations that are tagged with the *Narration* concept but are not tagged with the *Plot* concept (asserted concepts are marked with '+', while denied concepts are marked with '-'); the second criterion is named *Criticism* and selects annotations that are tagged with a sub-concept of *Criticism* but are not tagged with any sub-concept of *Structure*.

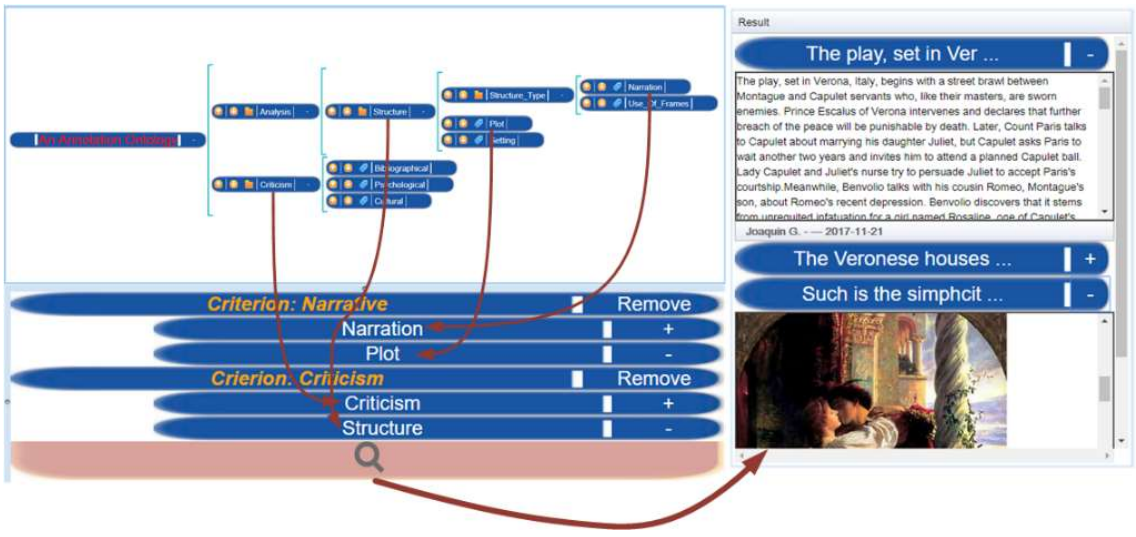
These functionalities are oriented to facilitate instructors in evaluating the quality of annotations. Instructors can use the annotation ontology to filter the annotations of each student, which enables the degree of compliance with the annotation objective to be assessed. Instructors can check the degree of consistency between the content of each annotation and the concepts used to classify it, which enables the extent to which the student has assimilated the conceptual structure that underlies the learning domains to be assessed. Instructors can also check if students have addressed all relevant aspects of the text or if they omitted an important aspect. This approach enables the instructors to evaluate the degree of detail and the comprehension achieved by the student during the reading of the content. These assessment facilities also promote continuous improvement of the annotation activity. Once the assessment results have been analyzed, the instructor can review his or her work and refine the critical annotation objectives and the ontology to improve student performance.

3.2. Pilot Experiment

To assess the impact of the proposed annotation paradigm in the students' learning performance, we undertook an experiment in the domain of *critical literary annotation*. *Critical literary annotation* is one of the basic competencies acquired in any literary program at university level. In critical literary annotation, students describe how a literary text is built and functions. Annotations are typically linked to text fragments and can exhibit various types: explanation of historical context, linguistic aspects, semantic aspects, influences, literary style, etc. [18].



(**a**)



(**b**)

Figure 3. (**a**) Basic filtering of annotations in @note; (**b**) advanced filtering.

We framed our experiment in a French literature course in a French Studies degree program. The pilot involved 28 students who were enrolled in the course. As previously mentioned, this relatively small number of students in a typical advanced course of a university-level degree program in the literature, compelled us to adopt a *within-subject* approach. Contrary to typical (*between-subject*) experimental designs that are based on a control group and experimental group, in a *within-subject* design, every participant is subjected to every treatment, which significantly contributes to the reduction of the variance and the number of required participants. Its main disadvantage is the potential presence of carryover effects (e.g., fatigue or practice), which can thread internal validity. In our case, we estimated the impact of these carryover effects in the final results to be negligible (Section 5). The pilot ran as follows:

- After reviewing the key principles of structural and thematic narratology for the analysis of narrative texts, the students were instructed in the conventional practice of annotation with paper and pencil [62] to initiate a narrative-type analysis.
- Then, they were asked to annotate a first text obtained from *Les Liaisons Dangereuses* by eighteenth-century French author Choderlos de Laclos (Amsterdam, Durand, 1784). This activity was employed as a baseline in the *within-subject* design. Twenty-six of the 28 students participated in this activity (two absences were recorded). Students worked during a one-hour class session and were given the option to finalize the activity during the following week.
- In parallel, an annotation activity was designed in *@note* for a second text, which was also obtained from *Les Liaisons Dangereuses* with a complexity that was similar to that of the baseline activity. Figure 4 outlines the annotation ontology provided by the instructor. As the ontology is aimed at students of French Studies, the instructor used French to name the concepts. This ontology includes and structures basic concepts related to the analysis of a narrative text following narratological criteria. The ontology introduces intermediate concepts of the first level to capture the main aspects contemplated in narratology [63]: sociocultural aspects of the text (*Contexte socio-culturel* concept), aspects related to the space (*Espace*) of the narration (i.e., to the frame or place where the events occur and the characters are placed), temporal aspects of the narrative (*Temps*), actors that lead the action (*Actants*), aspects related to the author (*Auteur*), aspects related to the narrator (*Narrateur*), and aspects related to discourse analysis (*Discours*). These aspects are refined in terms of more elementary narratological concepts, as the ontology outlined in Figure 4 indicates. In this way, this ontology guides students in the process of analyzing a narrative text following very well-defined narratological criteria. The ontology is applicable and reusable in other contexts. This fact is reflected in the average number of sub-concepts for each intermediate concept (4.43), which is a relatively high value that denotes the horizontal nature of the ontology [64].
- One week after completing the paper-and-pencil baseline annotation activity, a one-hour session was dedicated to instructing students in the critical annotation of texts with *@note*. In the next session, students undertook the *@note* activity and worked in class for an additional hour, in which questions about the use of the tool were answered. Similar to the paper-and-pencil baseline activity, the students had a week to complete the critical annotation activity with *@note*. A total of 27 students participated in this activity: 25 of the 26 students who participated in the previous (paper-and-pencil-based) activity and 2 other students who had not attended this previous activity.

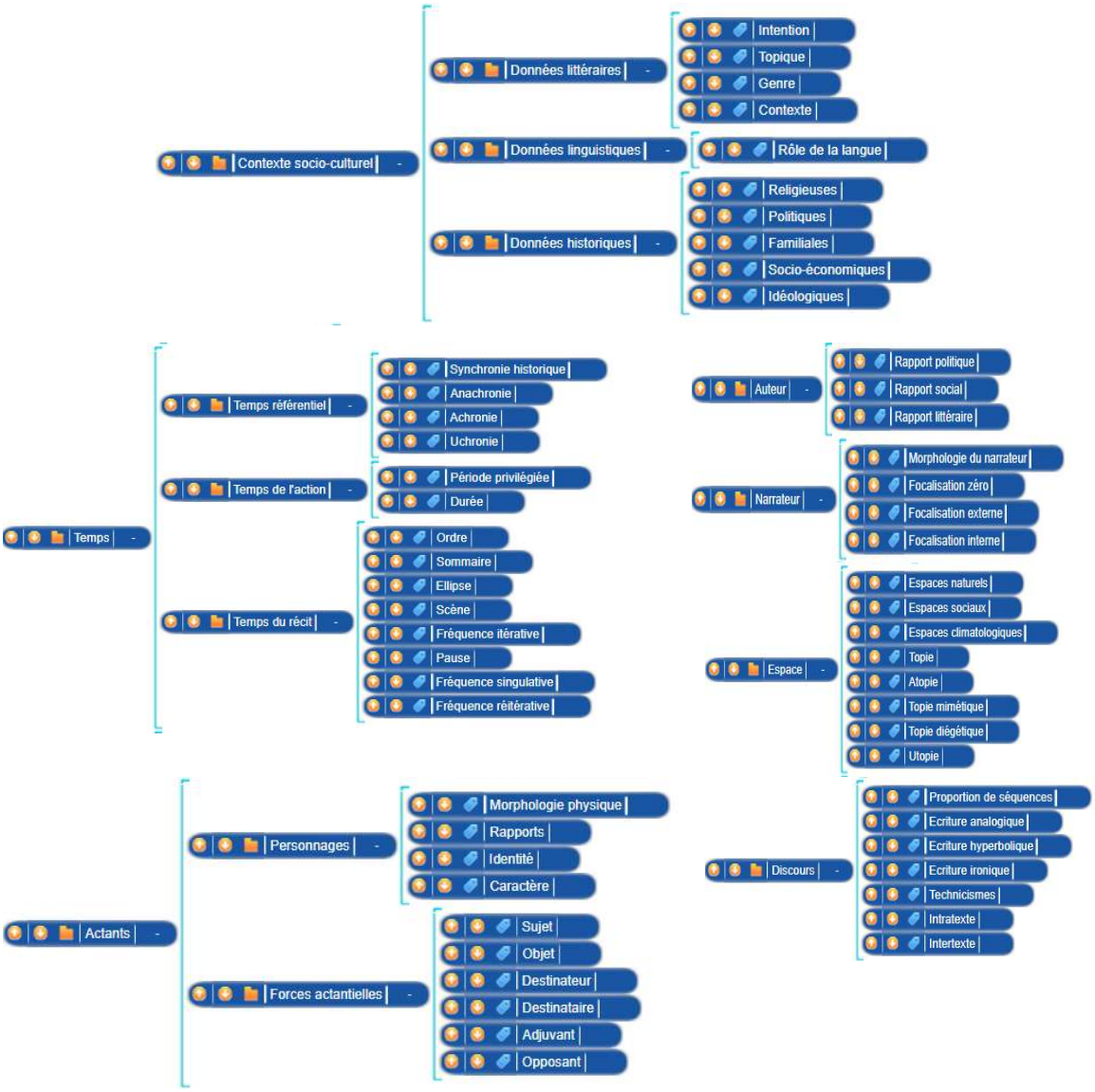


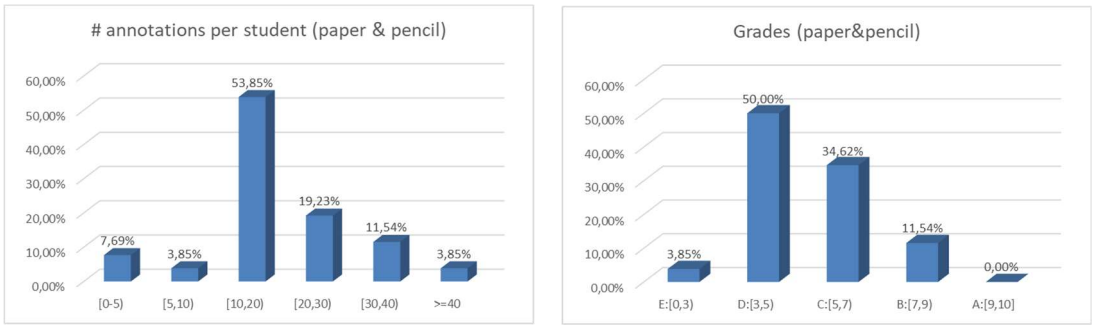
Figure 4. Annotation ontology for *Les Liaisons Dangereuses.*

4. Results

This section details the results of the pilot experiment. Section 4.1 summarizes the results of the activity based on paper and pencil. Section 4.2 describes the results of the activity based on *@note*. Section 4.3 provides a comparison.

4.1. Paper-and-Pencil-Based Annotation

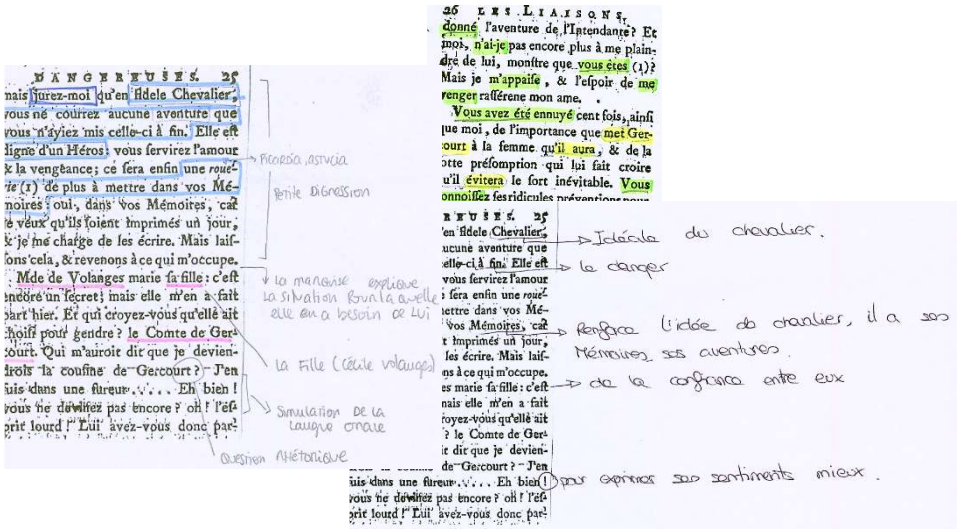
Figure 5a summarizes the distribution of the number of annotations per student for the 26 students who participated in the paper-and-pencil-based annotation activity (a total of 468 annotations were recorded). More than 53% of the students produced between 10 and 20 annotations. The average number of annotations was 18 (95% CI [14.04, 21.96]). Once the annotations were analyzed by the instructor, the shortcomings expected of an unguided annotation activity formulated in a complex domain such as *critical literary analysis* were detected:



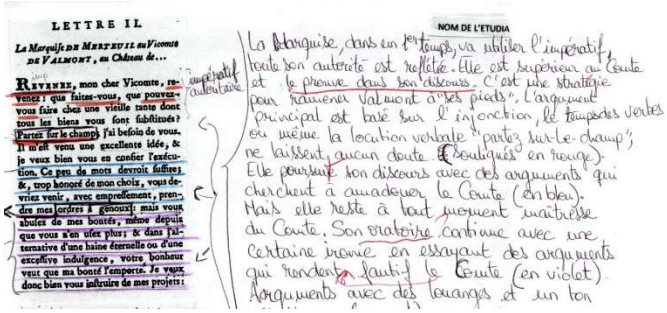
(**a**) (**b**)

Figure 5. Distributions (paper and pencil) of (**a**) number of annotations produced by students (x-axis: number of annotations interval; y-axis: percentage of students who produced annotations in the corresponding interval), and (**b**) grades obtained by the students (x-axis: grade intervals, y-axis: number of students who obtained a grade in each interval); grades have been grouped into 5 categories (from E, the worst one, to A, the best one) following standard criteria of the Spanish educational system.

- Annotations with limited content (a simple underline, a succinct sentence, or some lines of text, as shown in Figure 6a) and more elaborated annotations, but barely connected to the text and closer to the final critical analysis of the work were identified (Figure 6b).



(**a**)



(**b**)

Figure 6. Examples of paper and pencil-based annotations: (**a**) examples of succinct annotations; (**b**) example of elaborated annotations.

- As shown in Figure 6, students usually adopted many different annotation styles, which indicates a lack of systematicity during annotation.

- As also reflected in Figure 6, superfluous annotations that were minimally related to the narratological principles and many critical aspects that were not considered were frequently observed.

As a result, the grades for the activity were not satisfactory. Figure 5b shows the distribution of these grades, which were grouped into 5 categories (from E, the worst grade, to A, the best grade). Most of the students (approximately 54%) do not obtain the minimum grade to pass (C or higher). The average score (4.5, 95% CI [4.01, 4.99]) is below 5, which is the minimum grade to pass.

4.2. Annotation with @note

Concerning the activity with *@note*, 490 annotations were produced. A small number (42) of annotations were classified with concepts proposed by the students and grouped in the category *Autre* (*other*; Figure 7). Figure 8a summarizes the distribution of the 490 annotations produced by the 27 students who participated in the activity with *@note*. More than 51% of the students produced between 10 and 20 annotations. The average number of annotations produced by each student was 18.15 (95% CI [14.68, 21.62])

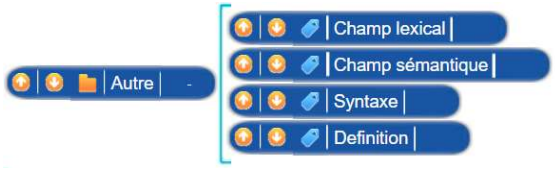
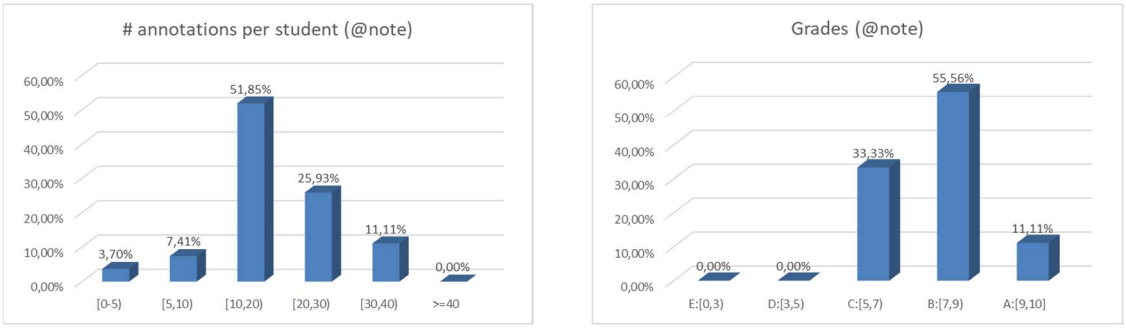


Figure 7. Concepts suggested by the students.



(**a**) (**b**)

Figure 8. Distributions (@note) of (**a**) number of annotations produced by students, (**b**) grades obtained by the students (x-axis: grade intervals, y-axis: number of students who obtained a grade in each interval).

Concerning the *quality* of the annotations:

- The instructor observed a greater homogenization in the annotation process due to the annotation discipline introduced by the ontology-guided approach and imposed by the tool. The heterogeneity in the annotation modes disappeared in favor of a single annotation format based on a semantic tagging of the annotations and an elaboration in the form of an enriched free text (Figure 9).
- The instructor observed a considerably more systematic critical annotation process: the students were forced to tag their annotations with concepts with a strong semantic charge and include strong arguments that support tagging, which contributed to a decrease in superfluous annotations.

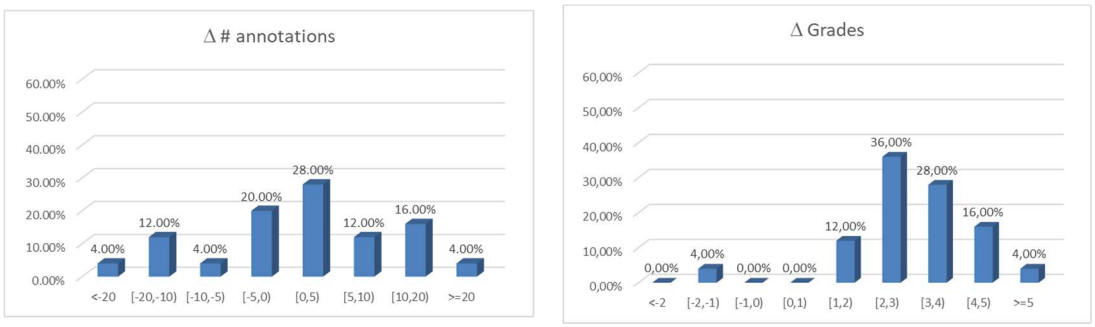
Figure 9. Examples of the elaborated @note-based annotations.

Therefore, the activity outcomes were significantly better than those of the baseline, conventional paper-and-pencil activity as shown by the distribution of grades for the activity with *@note* shown in Figure 8b. The average score is 6.93 (95% CI [6.42, 7.42]). All students obtained sufficient qualification (minimum of 5) to pass the activity.

4.3. Comparison

The number of annotations produced by the students does not significantly differ between the paper-and-pencil and the *@note* annotation activities:

- The average number of annotations are very similar in both activities (18 in the paper-and-pencil activity versus 18.15 in the *@note* one). Likewise, no statistically significant difference is observed between distributions in Figures 5a and 8a (Mann–Whitney U test: U = 339, $p = 0.830$).
- Figure 10a shows the distribution of the difference between the number of annotations produced with *@note* and the number of annotations produced with paper and pencil for the 25 students that participated in both activities. Although there is a tendency toward positive differences (40% negative versus 60% positive), this trend is not overwhelming. Consequently, the average of the difference in the number of annotations is 0.44 (95% CI [−3.7, 4.6]), and no statistically significant evidence is observed in favor of a non-zero median for the distribution (Wilcoxon signed rank test of the number of annotations for each student in both activities: Z = 150, $p = 0.715$).



(**a**) (**b**)

Figure 10. Distributions of (**a**) differences in annotations produced by each student (annotations in *@note* - annotations in paper-and-pencil activity), and (**b**) differences in grades (grades *@note* − grades paper-and-pencil).

However, the final grades were significantly better with *@note*:

- The average score with *@note* is almost 2.5 points above the average score in the activity based on pencil and paper. The improvement is statistically significant (Mann–Whitney U test of the scores in both activities: U = 639, $p = 0.000$).
- This improvement is also shown when the analysis focuses on the improvement that is individually obtained by each student. Taking into account the 25 participants who engaged in both activities, Figure 10b shows the distribution of the differences in the grades between the *@note* activity and the paper-and-pencil activity. Most of the students (84%) increased the grade obtained by more than 2 points. The average improvement does not significantly differ from the previously indicated value (2.44 points, 95% CI [1.87, 3.01]). The corresponding Wilcoxon signed rank test yields statistically significant evidence (Z = 316.5, $p = 0.000$) in favor of the improvement (median of the difference distribution is positive).

5. Discussion

The pilot's outcomes suggest that the ontology-driven approach can enhance the learning results with respect to an unguided, conventional paper-and-pencil-based document annotation approach. A significant improvement in the quality of the annotations produced with the tool was observed with respect to those that were produced using the conventional method based on paper and pencil. The students produced annotations that were better situated and more reasonable than those observed in the paper-and-pencil activity, in which annotations that were irrelevant from a critical analysis perspective proliferated. Students applied the free-text part of the annotation to justify the reason for the selected semantic concepts, argue how these concepts were reflected and developed in the text, and delve into the subtleties and complexities of the texts. Also, they omitted considerably fewer relevant aspects than the conventional paper-and-pencil approach (because the ontology already suggested to the students the aspects to seek and to be identified in the text). As a natural consequence of these improvements, the grades obtained with the tool were significantly better than those in the case based on paper and pencil.

Note the proposal by the students of the final concepts shown in Figure 7. The students proposed purely linguistic concepts such as "lexical field" and "semantic field", which are purely formal (as much as they can be "adjective" or "verb") instead of using more analytical and interpretative categories, such as "analogical writing" or "hyperbolic writing". In the context of the critical analysis of the text promoted by this activity, these needs enabled a diagnose of the lack of assimilation of the theory of analysis by some of the students who proposed and employed these concepts (an expected lack due to the knowledge-demanding nature of the critical literary annotation domain) rather than consideration of this lack as a weakness of the annotation ontology. Since *@note* enables students to

propose concepts using this feature, it also partially illustrates the shortcomings of approaches such as the folksonomy-based approaches.

Concerning the internal validity of the results, we consider it unlikely that the observed enhancements were attributed to the potential carryover effects (fatigue or practice) of the *within-subject* design approach that was adopted in the pilot.

- Fatigue was avoided since the annotation activities (baseline, paper-and-pencil, and *@note* activities) were performed in a separated session, and in both cases, students had sufficient time to complete the work in a calm way (one week).
- Potential carryover effects due to practice were minimized. As the baseline activity was based on paper and pencil instead of another annotation tool, the previous practice of students with other annotation tools for critical annotation was explicitly avoided. In addition, the text in the *@note* activity was different from the text in the baseline activity and the two annotation activities obeyed two radically different annotation paradigms: unguided, free-style annotation in the baseline activity vs. ontology-guided annotation in the activity that involved *@note*. Therefore, we estimated the probability that the experience in the critical annotation gained by the students during the baseline activity had significantly influenced the realization of the activity with *@note* to be negligible.

6. Conclusions and Future Research

In this paper, we have described an ontology-driven approach to educational document annotation activities. This approach is particularly valuable for guiding students during the annotation of documents in complex learning domains, in which a considerable amount of expert knowledge is required. The approach has been implemented in *@note*, which is an annotation tool aimed at educational activities that require high cognitive skills. *@note* enables instructors to configure all aspects of an annotation activity. The central element of this process is the formulation of the annotation ontology. This ontology guides students during the annotation of the document since, instead of adding annotations in an unstructured way, they are forced to classify their annotations with the concepts of the ontology. The combination of free-text annotations with semantic annotations confers to *@note* a distinctive feature that is not present in any of the analyzed annotation tools. Therefore, each annotation must be clearly justified in relation to the annotation objectives reflected by the ontology, which promotes meta-reflective thinking in students. Consequently, as shown by the pilot, the learning results can be substantially improved.

We are currently exploring the application of the ontology-driven approach to contexts other than the critical annotation of literary texts. In particular, and in a context of teacher training for kindergarten education, we are applying *@note* for the interpretation of image-based children's storybooks [65]. We are also exploring the application of the approach to code reading activities in programming [66], as well as to activities of requirement analysis and transformation in software development, e.g., systematic development of compilers from specifications based on attribute grammars [67,68]. Another promising use of *@note* follows from its integration inside *Clavy*, a platform for building learning object repositories with reconfigurable structures [69–71]. In this setting, we use *@note* to enable healthcare students to annotate clinical images in radiologic reports that are integrated in radiology-specific collections of learning objects [72–74]. Finally, we consider it interesting to explore the possibility of simultaneous collaborative formulation of ontologies during the critical annotation process, involving more expert annotators, as well as the interplay between collaborative annotations by a group of more experienced students with the ontology-guided approach described in this paper.

Author Contributions: Conceptualization, M.G.-d.-J., A.S.-C. (Amelia Sanz-Cabrerizo) and J.-L.S.; Data curation, J.G.-C., M.G.-A. and J.-L.S.; Formal analysis, M.G.-A., A.S.-C. (Antonio Sarasa-Cabezuelo) and J.-L.S.; Funding acquisition, M.G.-J., A.S.-C. (Antonio Sarasa-Cabezuelo) and J.-L.S.; Investigation, J.G.-C., M.G.-J. and A.S.-C. (Amelia Sanz-Cabrerizo); Methodology, M.G.-A., A.S.-C. (Antonio Sarasa-Cabezuelo) and J.-L.S.; Project administration, J.-L.S.; Resources, J.G.-C., M.G.-J., M.G.-A., A.S.-C. (Amelia Sanz-Cabrerizo), A.S.-C. (Antonio Sarasa-Cabezuelo) and J.L.-S.; Software, J.G.-C., M.G.-A., A.S.-C. (Antonio Sarasa-Cabezuelo) and J.L.-S.; Supervision, J.-L.S.; Validation, M.G.-J. and A.S.-C. (Amelia Sanz-Cabrerizo); Visualization, J.G.-C. and J.-L.S.; Writing—original draft, J.-L.S.; Writing—review & editing, J.G.-C., M.G.-J., M.G.-A., A.S.-C. (Amelia Sanz-Cabrerizo), A.S.-C. (Antonio Sarasa-Cabezuelo) and J.-L.S.

Funding: This research was funded by the Spanish Ministry of Science, Innovation and Universities grant numbers TIN2014-52010-R (RedR+Human) and TIN2017-88092-R (CetrO+Spec) and by the Community of Madrid, grant number S2015/HUM-3426 (e-Lite CM).

Acknowledgments: The development of *@note* was initially supported by two awards of the Google's Digital Humanities Award Programs (2010 and 2011 editions).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Colglazier, W. Sustainable development agenda: 2030. *Science* **2015**, *349*, 1048–1050. [CrossRef]
2. Wu, J.; Guo, S.; Huang, H.; Liu, W.; Xiang, Y. Information and Communications Technologies for Sustainable Development Goals: State-of-the-Art, Needs and Perspectives. *IEEE Commun. Surv. Tutor.* **2018**, *20*, 2389–2406. [CrossRef]
3. Daniela, L.; Visvizi, A.; Gutiérrez-Braojos, C.; Lytras, M.D. Sustainable Higher Education and Technology-Enhanced Learning (TEL). *Sustainability* **2018**, *10*, 3883. [CrossRef]
4. Mayes, J.; Morrison, D.; Mellar, H.; Bullen, P.; Oliver, M. *Transforming Higher Education through Technology-Enhanced Learning*; Higher Education Academy: York, UK, 2009; ISBN 978-1-907207-11-2.
5. Kawase, R.; Herder, E.; Nejdl, W. A Comparison of Paper-Based and Online Annotations in the Workplace. In *Learning in the Synergy of Multiple Disciplines, Proceedings of the 4th European Conference on Technology Enhanced Learning, Niza, France 29 September–2 October 2009*; Cress, U., Dimitrova, V., Specht, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2009; pp. 240–253.
6. Chen, C.-M.; Chen, F.-Y. Enhancing digital reading performance with a collaborative reading annotation system. *Comput. Educ.* **2014**, *77*, 67–81. [CrossRef]
7. Sung, H.-Y.; Hwang, G.-J.; Liu, S.-Y.; Chiu, I.-H. A prompt-based annotation approach to conducting mobile learning activities for architecture design courses. *Comput. Educ.* **2014**, *76*, 80–90. [CrossRef]
8. Kawasaki, Y.; Sasaki, H.; Yamaguchi, H.; Yamaguchi, Y. Effectiveness of highlighting as a prompt in text reading on a computer monitor. In Proceedings of the 8th WSEAS International Conference on Multimedia systems and signal processing (WSEAS), Hangzhou, China, 6–8 August 2008; pp. 311–315.
9. Jan, J.-C.; Chen, C.-M.; Huang, P.-H. Enhancement of digital reading performance by using a novel web-based collaborative reading annotation system with two quality annotation filtering mechanisms. *Int. J. Human-Comput. Stud.* **2016**, *86*, 81–93. [CrossRef]
10. Mendenhall, A.; Johnson, T.E. Fostering the development of critical thinking skills, and reading comprehension of undergraduates using a Web 2.0 tool coupled with a learning system. *Interact. Learn. Environ.* **2010**, *18*, 263–276. [CrossRef]
11. Hwang, W.-Y.; Wang, C.-Y.; Sharples, M. A study of multimedia annotation of Web-based materials. *Comput. Educ.* **2007**, *48*, 680–699. [CrossRef]
12. Johnson, T.E.; Archibald, T.N.; Tenenbaum, G. Individual and team annotation effects on students' reading comprehension, critical thinking, and meta-cognitive skills. *Comput. Human Behav.* **2010**, *26*, 1496–1507. [CrossRef]
13. Archibald, T.N. The Effect of the Integration of Social Annotation Technology, First Principles of Instruction, and Team-Based Learning on Students' Reading Comprehension, Critical Thinking, and Meta-Cognitive Skills. Ph.D. Thesis, The Florida State University, Tallahassee, FL, USA, 2010.

14. Nokelainen, P.; Kurhila, J.; Miettinen, M.; Floreen, P.; Tirri, H. Evaluating the role of a shared document-based annotation tool in learner-centered collaborative learning. In Proceedings of the 3rd IEEE International Conference on Advanced Technologies, Athens, Greece, 9–11 July 2003; pp. 200–203.
15. Nokelainen, P.; Miettinen, M.; Kurhila, J.; Floréen, P.; Tirri, H. A shared document-based annotation tool to support learner-centred collaborative learning. *Br. J. Educ. Technol.* **2005**, *36*, 757–770. [CrossRef]
16. Su, A.Y.S.; Yang, S.J.H.; Hwang, W.-Y.; Zhang, J. A Web 2.0-based collaborative annotation system for enhancing knowledge sharing in collaborative learning environments. *Comput. Educ.* **2010**, *55*, 752–766. [CrossRef]
17. Hsu, C.-K.; Hwang, G.-J.; Chang, C.-K. A personalized recommendation-based mobile learning approach to improving the reading performance of EFL students. *Comput. Educ.* **2013**, *63*, 327–336. [CrossRef]
18. Bauer, M.; Zirker, A. Explanatory Annotation of Literary Texts and the Reader: Seven Types of Problems. *Int. J. Humanit. Arts Comput.* **2017**, *11*, 212–232. [CrossRef]
19. Kalboussi, A.; Mazhoud, O.; Kacem, A.H. Comparative study of web annotation systems used by learners to enhance educational practices: features and services. *Int. J. Technol. Enhanc. Learn.* **2016**, *8*, 129–150. [CrossRef]
20. Cigarrán-Recuero, J.; Gayoso-Cabada, J.; Rodríguez-Artacho, M.; Romero-López, M.-D.; Sarasa-Cabezuelo, A.; Sierra, J.-L. Assessing semantic annotation activities with formal concept analysis. *Expert Syst. with Appli.* **2014**, *41*, 5495–5508. [CrossRef]
21. Gayoso-Cabada, J.; Ruiz, C.; Pablo-Nuñez, L.; Cabezuelo, A.S.; Goicoechea-de-Jorge, M.; Sanz-Cabrerizo, A.; Sierra-Rodríguez, J.L. A flexible model for the collaborative annotation of digitized literary works. In Proceedings of the Digital Humanities 2012, DH 2012, Conference Abstracts, Hamburg, Germany, 16–22 July 2012; pp. 195–197.
22. Gayoso-Cabada, J.; Sanz-Cabrerizo, A.; Sierra, J.-L. @Note: An Electronic Tool for Academic Readings. In Proceedings of the 1st International Workshop on Collaborative Annotations in Shared Environment: Metadata, Vocabularies and Techniques in the Digital Humanities, Florence, Italy, 10 September 2013; pp. 1–4.
23. Gayoso-Cabada, J.; Sarasa-Cabezuelo, A.; Sierra, J.-L. Document Annotation Tools: Annotation Classification Mechanisms. In Proceedings of the 6th International Conference on Technological Ecosystems for Enhancing Multiculturality, Salamanca, Spain, 24–26 October 2018; pp. 889–895.
24. Pearson, J.; Buchanan, G.; Thimbleby, H.; Jones, M. The Digital Reading Desk: A lightweight approach to digital note-taking. *Int. Comput.* **2012**, *24*, 327–338. [CrossRef]
25. Kam, M.; Wang, J.; Iles, A.; Tse, E.; Chiu, J.; Glaser, D.; Tarshish, O.; Canny, J. Livenotes: A System for Cooperative and Augmented Note-taking in Lectures. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Portland, OR, USA, 2–7 April 2005; pp. 531–540.
26. Tront, J.G.; Eligeti, V.; Prey, J. Classroom Presentations Using Tablet PCs and WriteOn. In *Proceedings of the Proceedings of the 36th Annual Conference in Frontiers in Education (IEEE)*; San Diego, CA, USA, 27–31 October 2006, pp. 1–5.
27. Liao, C.; Guimbretière, F.; Anderson, R.; Linnell, N.; Prince, C.; Razmov, V. PaperCP: Exploring the Integration of Physical and Digital Affordances for Active Learning. In *Human-Computer Interaction–INTERACT 2007, Proceedings of the 11th IFIP Conference on Human-Computer Interaction Part II; Rio de Janeiro, Brazil, 10–14 September 2007*; Baranauskas, C., Palanque, P., Abascal, J., Barbosa, S.D.J., Eds.; Springer: Berlin/Heidelberg, Germany, 2007; pp. 15–28.
28. Chatti, M.A.; Sodhi, T.; Specht, M.; Klamma, R.; Klemke, R. u-Annotate: An Application for User-Driven Freeform Digital Ink Annotation of E-Learning Content. In Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies (IEEE), Kerkrade, The Netherlands, 5–7 July 2006; pp. 1039–1043.
29. Lu, J.; Deng, L. Examining students' use of online annotation tools in support of argumentative reading. *Australas. J. Educ. Technol.* **2013**, *29*, 161–171. [CrossRef]
30. Kahan, J.; Koivunen, M.-R.; Prud'Hommeaux, E.; Swick, R.R. Annotea: An open RDF infrastructure for shared Web annotations. *Comput. Netw.* **2002**, *39*, 589–608. [CrossRef]
31. Glover, I.; Hardaker, G.; Xu, Z. Collaborative annotation system environment (CASE) for online learning. *Campus-Wide Inform. Syst.* **2004**, *21*, 72–80. [CrossRef]

32. Lin, S.S.J.; Chen, H.Y.; Chiang, Y.T.; Luo, G.H.; Yuan, S.M. Supporting Online Reading of Science Expository with iRuns Annotation Strategy. In Proceedings of the 7th International Conference on Ubi-Media Computing (IEEE), Ulaanbaatar, Mongolia, 12–14 July 2014; pp. 309–312.
33. Chang, M.; Kuo, R.; Chang, M.; Kinshuk; Kung, H. Online annotation system and student clustering platform. In Proceedings of the 8th International Conference on Ubi-Media Computing (IEEE), Colombo, Sri Lanka, 24–26 August 2015; pp. 202–207.
34. Asai, H.; Yamana, H. Intelligent Ink Annotation Framework That Uses User's Intention in Electronic Document Annotation. In Proceedings of the 9th ACM International Conference on Interactive Tabletops and Surfaces, Dresden, Germany, 16–19 November 2014; pp. 333–338.
35. Glover, I.; Xu, Z.; Hardaker, G. Online annotation–Research and practices. *Comput. Educ.* **2007**, *49*, 1308–1320. [CrossRef]
36. Pereira Nunes, B.; Kawase, R.; Dietze, S.; Bernardino de Campos, G.H.; Nejdl, W. Annotation Tool for Enhancing E-Learning Courses. In *Advances in Web-Based Learning-ICWL 2012, Proceedings of the 11th International Conference on Web Based Learning, Sinaia, Romania, 2–4 September 2012*; Popescu, E., Li, Q., Klamma, R., Leung, H., Specht, M., Eds.; Springer: Berlin/Heidelberg, Germany, 2012; pp. 51–60.
37. Chen, Y.-C.; Hwang, R.-H.; Wang, C.-Y. Development and evaluation of a Web 2.0 annotation system as a learning tool in an e-learning environment. *Comput. Educ.* **2012**, *58*, 1094–1105. [CrossRef]
38. Cabanac, G.; Chevalier, M.; Chrisment, C.; Julien, C. A Social Validation of Collaborative Annotations on Digital Documents. In Proceedings of the International Workshop on Annotation for Collaboration, Paris, France, 23–24 November 2005; pp. 31–40.
39. Bonifazi, F.; Levialdi, S.; Rizzo, P.; Trinchese, R. A Web-based Annotation Tool Supporting e-Learning. In Proceedings of the Working Conference on Advanced Visual Interfaces, Trento, Italy, 22–24 May 2002; pp. 123–128.
40. Bottoni, P.; Civica, R.; Levialdi, S.; Orso, L.; Panizzi, E.; Trinchese, R. MADCOW: A Multimedia Digital Annotation System. In Proceedings of the Working Conference on Advanced Visual Interfaces, Gallipoli, Italy, 25–28 May 2004; pp. 55–62.
41. Lebow, D.G.; Lick, D.W. HyLighter: An effective interactive annotation innovation for distance education. In Proceedings of the 20th Annual Conference on Distance Teaching and Learning, Madison, WI, USA, 4–6 August 2004; pp. 1–5.
42. Kennedy, M. Open Annotation and Close Reading the Victorian Text: Using Hypothes.is with Students. *J. Vic. Cult.* **2016**, *21*, 550–558. [CrossRef]
43. Perkel, J.M. Annotating the scholarly web. *Nat. News* **2015**, *528*, 153–154. [CrossRef] [PubMed]
44. Paradis, J.; Fendt, K. *Annotation Studio-Digital Annotation as an Educational Approach in the Humanities and Arts (Tech. Report)*; MIT White Paper: Cambridge, MA, USA, 2016.
45. Anagnostopoulou, C.; Howell, F. Collaborative Online Annotation of Musical Scores for eLearning using A.nnotate.com. In Proceedings of the 3rd International Technology, Education and Development Conference (IATED), Valencia, Spain, 2–4 March 2009; pp. 4071–4079.
46. Tseng, S.-S.; Yeh, H.-C.; Yang, S. Promoting different reading comprehension levels through online annotations. *Comput. Assist. Lang. Learn.* **2015**, *28*, 41–57. [CrossRef]
47. Kim, J.-K.; Sohn, W.-S.; Hur, K.; Lee, Y. Increasing Learning Effect by Tag Cloud Interface with Annotation Similarity. *Int. J. Adv. Media Commun.* **2014**, *5*, 135–148. [CrossRef]
48. Bateman, S.; Brooks, C.; McCalla, G.; Brusilovsky, P. Applying Collaborative Tagging to E-Learning. In Proceedings of the Workshop on Tagging and Metadada for Social Information Organization-6th International World Wide Web Conference, Banff, AB, Canada, 8–12 May 2007; pp. 1–7.
49. Bateman, S.; Farzan, R.; Brusilovsky, P.; McCalla, G. OATS: The Open Annotation and Tagging System. In Proceedings of the Conference of the LORNET Research Network (I2LOR'2006), Montreal, QC, Canada, 8–10 November 2006; pp. 1–10.
50. Kawase, R.; Herder, E.; Nejdl, W. Annotations and Hypertrails With Spread Crumbs-An Easy Way to Annotate, Refind and Share. In Proceedings of the 6th International Conference on Web Information Systems and Technologies (INSTICC), Valencia, Spain, 7–10 April 2010.
51. Silvestre, F.; Vidal, P.; Broisin, J. Tsaap-Notes–An Open Micro-blogging Tool for Collaborative Notetaking during Face-to-Face Lectures. In Proceedings of the 14th IEEE International Conference on Advanced Learning Technologies (IEEE), Athens, Greece, 7–10 July 2014; pp. 39–43.

52. Hinze, A.; Heese, R.; Schlegel, A.; Luczak-Rösch, M. User-Defined Semantic Enrichment of Full-Text Documents: Experiences and Lessons Learned. In *Proceedings of the Theory and Practice of Digital Libraries, Paphos, Cyprus, 23–27 September 2012*; Zaphiris, P., Buchanan, G., Rasmussen, E., Loizides, F., Eds.; Springer: Berlin/Heidelberg Germany, 2012; pp. 209–214.
53. Luczak-Rösch, M.; Heese, R. Linked Data Authoring for Non-Experts. Proceedings of WWW2009 Workshop on Linked Data on the Web, Madrid, Spain, 20 April 2009; pp. 1–5.
54. Da Rocha, T.R.; Willrich, R.; Fileto, R.; Tazi, S. Supporting Collaborative Learning Activities with a Digital Library and Annotations. In *Proceedings of the Education and Technology for a Better World, Bento Gonçalves, Brazil, 27–31 July 2009*; Tatnall, A., Jones, A., Eds.; Springer: Berlin/Heidelberg Germany, 2009; pp. 349–358.
55. Azouaou, F.; Desmoulins, C. Teachers' document annotating: models for a digital memory tool. *Int. J. Contin. Eng. Educ. Life Long Learn.* **2006**, *16*, 18–34. [CrossRef]
56. Azouaou, F.; Desmoulins, C. MemoNote, a context-aware annotation tool for teachers. In Proceedings of the 7th International Conference on Information Technology Based Higher Education and Training (IEEE), Sydney, Australia, 10–13 July 2006; pp. 621–628.
57. Azouaou, F.; Mokeddem, H.; Berkani, L.; Ouadah, A.; Mostefai, B. WebAnnot: a learner's dedicated web-based annotation tool. *Int. J. Technol. Enhanc. Learn.* **2013**, *5*, 56–84. [CrossRef]
58. Kalboussi, A.; Omheni, N.; Mazhoud, O.; Kacem, A.H. An Interactive Annotation System to Support the Learner with Web Services Assistance. In Proceedings of the 15th IEEE International Conference on Advanced Learning Technologies, Hualien, Taiwan, 6–9 July 2015; pp. 409–410.
59. Barab, S.; Squire, K. Design-Based Research: Putting a Stake in the Ground. *J. Learn. Sci.* **2004**, *13*, 1–14. [CrossRef]
60. Greenwald, A.G. Within-subjects designs: To use or not to use? *Psychol. Bull.* **1976**, *83*, 314–320. [CrossRef]
61. Bennett, A.J.; Royle, N. *An Introduction to Literature, Criticism and Theory: Key Critical Concepts*; Prentice Hall/Harvester Wheatsheaf: Upper Saddle River, NJ, USA; London, UK, 1995; ISBN 0-13-355215-2.
62. Bold, M.R.; Wagstaff, K.L. Marginalia in the digital age: Are digital reading devices meeting the needs of today's readers? *Libr. Inf. Sci. Res.* **2017**, *39*, 16–22. [CrossRef]
63. Bal, M. *Narratology: Introduction to the theory of Narrative*, 4th Ed. ed; University of Toronto Press: Toronto, ON, Canada, 2017.
64. Tartir, S.; Arpinar, I.-B.; Moore, M.; Sheth, A.-P.; Aleman-Meza, B. OntoQA: Metric-Based Ontology Quality Analysis. Proceedings of IEEE Workshop on Knowledge Acquisition from Distributed, Autonomous, Semantically Heterogeneous Data and Knowledge Sources, Houston, TX, USA, 27 November 2005.
65. Lysaker, J.; Hopper, E. A Kindergartner's Emergent Strategy Use During Wordless Picture Book Reading. *Read. Teach.* **2015**, *68*, 649–657. [CrossRef]
66. Gómez-Albarrán, M. The Teaching and Learning of Programming: A Survey of Supporting Software Tools. *Comput. J.* **2005**, *48*, 130–144. [CrossRef]
67. Paakki, J. Attribute Grammar Paradigms—A High-level Methodology in Language Implementation. *ACM Comput. Surv.* **1995**, *27*, 196–255. [CrossRef]
68. Rodríguez-Cerezo, D.; Sarasa-Cabezuelo, A.; Gómez-Albarrán, M.; Sierra, J.-L. Serious games in tertiary education: A case study concerning the comprehension of basic concepts in computer language implementation courses. *Comput. Human Behav.* **2014**, *31*, 558–570. [CrossRef]
69. Gayoso-Cabada, J.; Gómez-Albarrán, M.; Sierra, J.-L. Query-Based Versus Resource-Based Cache Strategies in Tag-Based Browsing Systems. In *Maturity and Innovation in Digital Libraries, Proceedings of the 20th International Conference on Asia-Pacific Digital Libraries, Hamilton, New Zealand, 19–22 November 2018*; Dobreva, M., Hinze, A., Žumer, M., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 41–54.
70. Gayoso-Cabada, J.; Rodríguez-Cerezo, D.; Sierra, J.-L. Multilevel Browsing of Folksonomy-Based Digital Collections. In *Web Information Systems Engineering–WISE 2016, Proceedings of the 17th International Conference, Shanghai, China, 8–10 November 2016*; Cellary, W., Mokbel, M.F., Wang, J., Wang, H., Zhou, R., Zhang, Y., Eds.; Springer International Publishing: Cham, Switzerland, 2016; pp. 43–51.
71. Gayoso-Cabada, J.; Rodríguez-Cerezo, D.; Sierra, J.-L. Browsing Digital Collections with Reconfigurable Faceted Thesauri. In *Complexity in Information Systems Development, Proceedings of the 25th International Conference on Information Systems Development*; Goluchowski, J., Pankowska, M., Linger, H., Barry, C., Lang, M., Schneider, C., Eds.; Springer International Publishing: Cham, Switzerland, 2017; pp. 69–86.

72. Buendía, F.; Gayoso-Cabada, J.; Sierra, J.-L. From Digital Medical Collections to Radiology Training E-Learning Courses. In Proceedings of the 6th International Conference on Technological Ecosystems for Enhancing Multiculturality, Salamanca, Spain, 24–26 October 2018; pp. 488–494.
73. Buendía, F.; Gayoso-Cabada, J.; Sierra, J.-L. Using Digital Medical Collections to Support Radiology Training in E-learning Platforms. In *Lifelong Technology-Enhanced Learning, Proceedings of the 3th European Conference on Technology Enhanced Learning, EC-TEL 2018, Leeds, UK, 3–5 September 2018*; Pammer-Schindler, V., Pérez-Sanagustín, M., Drachsler, H., Elferink, R., Scheffel, M., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 566–569.
74. Buendía, F.; Gayoso-Cabada, J.; Sierra, J.-L. Generation of Standardized E-Learning Content from Digital Medical Collections. *J. Med. Syst.* **2019**, *43*, 188. [CrossRef]