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Perceptions of the use of intelligent information access systems in university level active learning activities among teachers of biomedical subjects

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ABSTRACT

Background: Student participation and the use of active methodologies in classroom learning are being increasingly emphasized. The use of intelligent systems can be of great help when designing and developing these types of activities. Recently, emerging disciplines such as 'educational data mining' and 'learning analytics and knowledge' have provided clear examples of the importance of the use of artificial intelligence techniques in education.

Objective: The main objective of this study was to gather expert opinions regarding the benefits of using complementary methods that are supported by intelligent systems, specifically, by intelligent information access systems, when processing texts written in natural language and the benefits of using these methods as companion tools to the learning activities that are employed by biomedical and health sciences teachers.

Methods: Eleven teachers of degree courses who belonged to the Faculties of Biomedical Sciences (BS) and Health Sciences (HS) of a Spanish university in Madrid were individually interviewed. These interviews were conducted using a mixed methods questionnaire that included 66 predefined close-ended and open-ended questions. In our study, three intelligent information access systems (i.e., BioAnnote, CLEiM and MedCMap) were successfully used to evaluate the teacher's perceptions regarding the utility of these systems and their different methods in learning activities.

Results: All teachers reported using active learning methods in the classroom, most of which were computer programs that were used for initially designing and later executing learning activities. All teachers used case-based learning methods in the classroom, with a specific emphasis on case reports written in Spanish and/or English. In general, few or none of the teachers were familiar with the technical terms related to the technologies used for these activities such as "intelligent systems" or "concept/mental maps". However, they clearly realized the potential applicability of such approaches in both the preparation and the effective use of these activities in the classroom. Specifically, the themes highlighted by a greater number of teachers after analyzing the responses to the open-ended questions were the usefulness of BioAnnote system to provide reliable sources of medical information and the usefulness of the bilingual nature of CLEiM system for learning medical terminology in English.

Conclusions: Three intelligent information access systems were successfully used to evaluate the teacher's perceptions regarding the utility of these systems in learning activities. The results of this study showed that integration of reliable sources of information, bilingualism and selective annotation of concepts were the most valued features by the teachers, who also considered the incorporation of these systems into learning activities to be potentially very useful. In addition, in the context of our experimental conditions, our work provides useful insights into the way to appropriately integrate this type of intelligent information access systems into learning activities, revealing key themes to consider when developing such approaches.

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1. Introduction

Traditional models of learning, which involved the use of tests to assess the acquisition of knowledge regarding large blocks of information, have evolved toward methods in which both learning and its assessment are progressive. These models are part of a new paradigm of student-centered learning that was heavily emphasized in the trend report produced for the 2010 Bologna Anniversary Conference [1]. This report stressed the importance of designing activities that allow students to acquire knowledge via participation (active learning) rather than solely learning information through teacher-driven activities [2,3].

This novel and reoriented education model has been accompanied by the development of different collaborative learning methods involving the resolution of real and simulated cases. These learning methods might be applied via project work, problem-solving, case studies, or concepts or mental maps [4–13]; additionally, these methods can make use of information systems and even certain key features of traditional learning approaches [14–16]. In this context, the development of information technologies has led to the creation of new educational methods and learning activities such as e-learning, online learning, Internet-based learning or web-based learning, all of which marry well with student-centered learning [17–21].

The use of intelligent systems in general, as well as, intelligent information access (IIA) systems in particular (e.g., recommendation systems, search engines, keyword annotators, learning algorithms, etc.), is an emerging strategy that is being applied by certain virtual learning environments (VLE) and as a component of learning activities [22–25]. A good example of the extent to which intelligent systems are being incorporated into VLEs is the emergence of new scientific disciplines that study the application of text and data mining techniques within the field of education, such as educational data mining (EDM) and learning analytics and knowledge (LAK) [26–28].

The application of IIA systems in the biomedical domains is becoming a reality. In this context, the ability to automatically search for concepts in natural language medical texts has been under continuous development for approximately 20 years. MedLEE [29] was one of the first systems designed to extract clinical information from unstructured text, linking it to terms belonging to a controlled vocabulary entitled SNOMED CT [30]. Appearing in 1994, it was used to process radiological reports [31]. Another major system, MetaMap [32], which was developed by the National Library of Medicine (NLM), is focused on the identification of concepts that best represent text introduced by a user [33]. An excellent review of these information systems and their applications is available in the article authored by Meystre et al. [34].

Given the practical nature of the health professions, active learning methods have been rapidly adopted in medical education. This fact has been accompanied by increased development of intelligent systems that utilize these methods, e.g., tools that incorporate semantic information via annotation [35,36], and annotation and recovery systems based on the use of ontologies [37–39].

The ability of these types of systems to enable the integration of knowledge sources and, thus, allow end-users to recover descriptive information on the elements extracted or to delve further into these data using concepts related to the elements that are recognized is without precedence. In addition, although some IIA systems have been successfully tested in educational settings, there is a lack of knowledge of: (*i*) teachers' perceptions of these systems and their use in learning activities; and (*ii*) teachers' knowledge regarding the text mining techniques applied to process user input.

Taking into consideration the aforementioned findings, in our current work, we designed and carried out individual semi-structured interviews with BS and HS faculty members to gather expert opinions regarding the benefits of using different methods and IIA systems to process natural language texts and the utility of these methods as tools in the application of learning activities. Specifically, questions were designed to collect information around the following main blocks: (*1*) general information and knowledge of active teaching methods; (*2*) knowledge related to concept annotation; (*3*) knowledge related to cross-lingual concept extraction; (*4*) knowledge related to concept/mental maps; and (*5*) classification of the examined IIA systems.

2. Methods

2.1. Study design

Mixed methods [40] are commonly used to assess satisfaction with and perceptions of the use of information systems in education in general [41–43] and biomedical education in particular [44]. In this line of thought, surveys of user perceptions have received special attention in the scientific community [45–47].

The present study adopted a mixed methodology, making use of a questionnaire that included a set of close-ended questions that allowed for the quantitative analysis of data and a set of open-ended questions that enabled the collection of qualitative data regarding the teachers' opinions via semi-structured interviews, an approach that permitted the interviewer to clarify previous answers and complement the questionnaire with extra data. In addition to the collection of data regarding the interviewee's personal information and background, the questionnaire focused on the main topics of study, such as information tools and sources of information; case-based learning (CBL) methods and the use of case reports; intelligent systems and natural language processing (NPL); knowledge related to concept annotation; knowledge related to cross-lingual concept extraction; and knowledge related to conceptual or mental maps. To this end, BioAnnote [48,49], CLEiM [50] and MedCMap [51] were chosen to evaluate the teacher's perceptions of the use of IIA systems based on concept annotation, cross-lingual concept extraction, and conceptual or mental maps in learning activities.

Table 1
Organization of the questionnaire: blocks and question categories.

Block	Category
General information and knowledge of active learning methods	1. Personal information and background
	2. Information tools and sources of information used in the preparation or execution of active learning activities
	3. CBL methods and the use of case reports
	4. Intelligent systems and NLP systems in the classroom
Knowledge related to concept annotation	5. Use of annotators
	6. Opinions regarding the use of the **BioAnnote** annotation system in learning activities
Knowledge related to cross-lingual concept extraction	7. Use of monolingual and cross-lingual concept extraction systems
	8. Opinions regarding the use of the **CLEiM** cross-lingual concept extraction system in learning activities
Knowledge related to concept/mental maps	9. Use of concept/mental maps
	10. Opinions regarding the use of the **MedCMap** mental map system in learning activities
Arrangement of the examined IIA systems	11. How would you order the systems evaluated herein in terms of their usefulness in teaching? (decreasing order by perceived usefulness)

Table 2
Description of the specific questions and their response options in each category.

Category	Question	Response options
1	Sex	Male/Female
	Age	
	Faculty/School	
	Subjects taught/Level of classes taught	
	Years of teaching experience	
	What do you believe you level of English proficiency to be?	High/Medium/Low
	What do you believe your students' average level of English proficiency to be?	High/Medium/Low
	Computer knowledge (with clarification the meaning of these levels)	Expert/Advanced/User
2	Do you use computers in the classroom?	Yes/No
	How do you use the computers?	Open-ended
	Do you use active learning methods?	Yes/No
	Which active learning methods do you use?	Open-ended
	What computer programs do you use to prepare activities?	Open-ended
	What programs do you use to carry out these activities in the classroom?	Open-ended
	What programs do the students use while engaging in these activities?	Open-ended
	What are the three most important web-based information sources you use in your teaching activities?	Open-ended
3	Are you aware of the existence of the CBL methods?	Yes/No
	Do you use CBL methods?	Yes/No
	Do you use case reports?	Yes/No
	Where do you obtain your case reports?	Open-ended
	In what language are the case reports written?	English/Spanish/Both
	How do you use the case reports?	Open-ended
4	Do you know (in basic terms) what an intelligent system is?	Yes/No
	Do you use any intelligent systems for preparing learning activities?	Yes/No
	Do you use any intelligent systems in the classroom?	Yes/No
	Which intelligent systems do you use?	Open-ended
	Do you know (in basic terms) what NLP systems are?	Yes/No
	Do you use any NLP systems for preparing learning activities?	Yes/No
	Do you use any NLP systems in the classroom?	Yes/No
	Which NLP systems do you use?	Open-ended
5	Do you know what a natural language text annotator is?	Yes/No
	Do you use any natural language text annotators to prepare learning activities?	Yes/No
	Do you use any natural language text annotators in the classroom?	Yes/No
	Which natural language text annotators do you use?	Open-ended
	Do you think natural language text annotators might be useful for preparing CBL activities?	Yes/No
	Do you think natural language text annotators might be useful for executing CBL activities in the classroom?	Yes/No
6	Q1. Do you think the BioAnnote system is useful for preparing CBL activities?	Likert 1–5
	Q2. Do you think the BioAnnote system is useful for executing CBL activities in the classroom?	Likert 1–5
	Respondent's comments regarding the system	Open-ended
7	Do you know what a natural language concept extraction system is?	Yes/No
	Do you use any natural language concept extraction systems to prepare learning activities?	Yes/No
	Do you use any natural language concept extraction systems in the classroom?	Yes/No
	Which natural language concept extraction systems do you use?	Open-ended
	Do you know what a cross-lingual concept extraction system is?	Yes/No
	Do you use any cross-lingual concept extraction systems to prepare learning activities?	Yes/No
	Do you use any cross-lingual concept extraction systems in the classroom?	Yes/No
	Which cross-lingual concept extraction systems do you use?	Open-ended
	Do you think cross-lingual concept extraction systems would be useful in preparing CBL activities?	Yes/No
	Do you think cross-lingual concept extraction systems would be useful in executing CBL activities in the classroom?	Yes/No
8	Q1. Do you think the CLEiM system is useful for preparing CBL activities?	Likert 1–5
	Q2. Do you think the CLEiM system is useful for executing CBL activities in the classroom?	Likert 1–5
	Respondent's comments regarding the system	Open-ended
9	Do you know what concept/mental maps are?	Yes/No
	Do you know how to execute an activity based on concept/mental maps?	Yes/No
	Have you ever executed an activity based on concept/mental maps?	Yes/No
	How did you undertake this activity?	Open-ended
	Do you know of any computer tool that could help in this sort of activity?	Yes/No
	Have you ever used a computer tool to prepare an activity of this sort?	Yes/No
	Have you ever used a computer tool in the classroom?	Yes/No
	Open-ended	Open-ended
	Do you think conceptual/mental maps based computer tool would be of use for preparing this type of activity?	Yes/No
	Do you think concept/mental maps based computer tool would be useful for executing this type of activity in the classroom?	Yes/No
10	Q1. Do you think the MedCMap system is useful for preparing CBL activities?	Likert 1–5
	Q2. Do you think the MedCMap system is useful for executing CBL activities in the classroom?	Likert 1–5
	Respondent's comment regarding the system	Open-ended
11	How would you order the systems presented in terms of their usefulness in teaching? (decreasing order)	3/2/1

2.2. Questionnaire design

A questionnaire was designed that included questions clustered into eleven categories directly related to the main topics of study. Table 1 show how these categories were grouped into five complementary blocks: (1) general information and knowledge of active teaching methods; (2) knowledge related to concept annotation; (3) knowledge related to cross-lingual concept extraction; (4) knowledge related to concept/mental maps and (5) arrangement of the evaluated IIA systems in decreasing order by perceived usefulness.

The questionnaire, which included a total of 66 questions, is shown in Table 2. As previously mentioned, the interviews included both

quantitative and qualitative questions. Examples of quantitative questions (i.e., close-ended questions) included the following: (*i*) questions regarding "Age" and "Years of teaching experience"; (*ii*) fixed response questions, such as "Sex (male/female)" or "What do you believe your level of English proficiency to be? (high/medium/low)"; and (*iii*) Likert-type scale questions with responses ranging from 1 to 5, where 1 indicated "strongly disagree" and 5 indicated "strongly agree" (e.g., "Do you think the BioAnnote system is useful for preparing CBL activities?").

Qualitative questions (i.e., open-ended questions) allowed for the discussion to be extended beyond the script, providing deeper levels of information. Examples of this type of question include the following: "What computer programs do you use to prepare activities?" and "What programs do you use to carry out these activities in the classroom?". A more detailed description of the questions included within each category is provided in Appendix A.

2.3. IIA systems for learning activities

To gain an understanding of the perceptions of the teachers regarding the application of IIA systems based on concept annotation, cross-lingual concept extraction and conceptual or mental maps in learning activities, the BioAnnote, CLEiM and MedCMap systems were respectively used. These three systems use text mining techniques to automatically extract medical concepts from inputted case reports. In addition, all of these systems allow users to obtain additional information regarding the concepts extracted and semantically related concepts. The three systems collect all output information under a single interface. However, from an end-user point of view, the functions offered by these systems differ significantly from one another. Table 3 shows the main characteristics of each analyzed system. The following is a detailed description of the characteristics and functionalities of each of the three systems.

2.3.1. BioAnnote system

BioAnnote [48,49] is a IIA system for the automatic annotation of biomedical resources. BioAnnote integrates a component previously developed with the AIBench Framework software [8,52]. A representative image of this system is shown in Fig. 1. The BioAnnote system includes: (i) a desktop application that allow users to annotate biomedical texts by using different high-quality online, such as Medlineplus and Freebase; (ii) an extensible and embeddable annotation meta-server to annotate documents using local or remote ontologies; and (iii) a client/server protocol to enable the use this meta-server by third-party applications. By using the BioAnnote system, users can submit biomedical documents and obtain annotations for the relevant terms (e.g. diseases, symptoms and treatments) from the BioAnnote server ontologies (Medlineplus and Freebase) or online NCBO ontologies. BioAnnote also allows users to retrieve detailed information for each annotated entity, including related topics, external links, related bibliography and paper abstracts. In addition, this system includes a powerful scripting engine able to perform batch annotations. Bioannote is available, as opensource software, for the main

Table 3
Main features of the analyzed systems.

System	User interface	Process	Information languages
BioAnnote	Desktop	Annotates over the text	English
CLEiM	Web	Extracts a list of medical entities	English/Spanish
MedCMap	Web/applet	Extracts a list and draws a concept map	English

2.3.2. CLEiM system

CLEiM (Cross Lingual Education in Medicine) [50], is a later version of the BioAnnote system. A representative image of this system is shown in Fig. 2. CLEiM maintains the same interface but includes new terms in the preprocessing stage and a cross-lingual information access system. Specifically, it is a java client-server web application which focus on named entity recognition (NER) in English and Spanish. CLEiM allows users to input a text containing medical terms (e.g. diseases, treatments, symptoms, etc.) and easily to deepen the meaning of these terms using the web navigator. The system uses preprocessed dictionaries from qualified sources as MedlinePlus and SnomedCT terminologies, and a working flow built with the NLP architecture GATE and integrated through the Java API provided by GATE. This preprocess stage is an offline task that does not slow down the online process followed by the user. Besides, the system uses information of several linked data to show more details and relations among the terms. The installation of the system requires a Java web server and it is available as opensource software.

2.3.3. MedCMap system

MedCMap system [51] integrates elements of BioAnnote with elements of the BuscaMed [53] software. BuscaMed is a web system for the visually assisted search of relevant biomedical information through a concept graph. The MedCMap system: (i) builds a concept graph through an initial concept referring a disease, discovering causes, symptoms and treatments; (ii) helps the user to define their information needs, how to express better the search string through the visual aid of the concept graph. The user receives complementary information of the selected concept, as translations, images, links, definitions and synonyms; (iii) makes a search on a list of pre-selected biomedical repositories. A representative image of this system is shown in Fig. 3. The MedCMap system is based on UMLS Metathesaurus (accessed through a REST API service) and on Wikidata (accessed through the MediaWiki API). The visual representation of retrieved information is made with Javascript library D3 displaying a force-directed graph. MedCMap system is available in English language.

2.4. Sample

To conduct our study, we selected 11 teachers with different training and experience backgrounds who taught BS and HS degree courses at the Universidad Europea de Madrid (UEM), Spain. The UEM Faculty of BS teaches medicine, dentistry, pharmacy and biotechnology, while the Faculty of HS teaches physiotherapy, chiropody, nursing and optometry. The sample was selected in an intentional and purposeful way, and teachers with complementary professional profiles and different areas of specialization and teaching experience were selected. The selection process was performed in accordance with previous studies in related thematic areas, both in the size and profile of the sample [46,54,55]. All members of these two faculties were asked to participate in the study, and a total of 11 teachers provided written consent to be interviewed and recorded. The respondents were assigned a numeric identification code to maintain their anonymity.

2.5. Data collection

The interviews were carried out by four university teachers, two from the Faculty of BS and two from the Faculty of Computer Science (CS). To ensure interview consistency, the first interview was performed with all four interviewers present, while the remaining interviews were carried out with one interviewer from each faculty. All interviews were recorded using professional audio equipment and digitally recorded using a computer equipped with appropriate software [56]. Their average duration was 45 min 5 s (ranging from 29 min 19 s to 1 h 1 min 3 s).

Output transcripts were generated by one of the interviewers, who

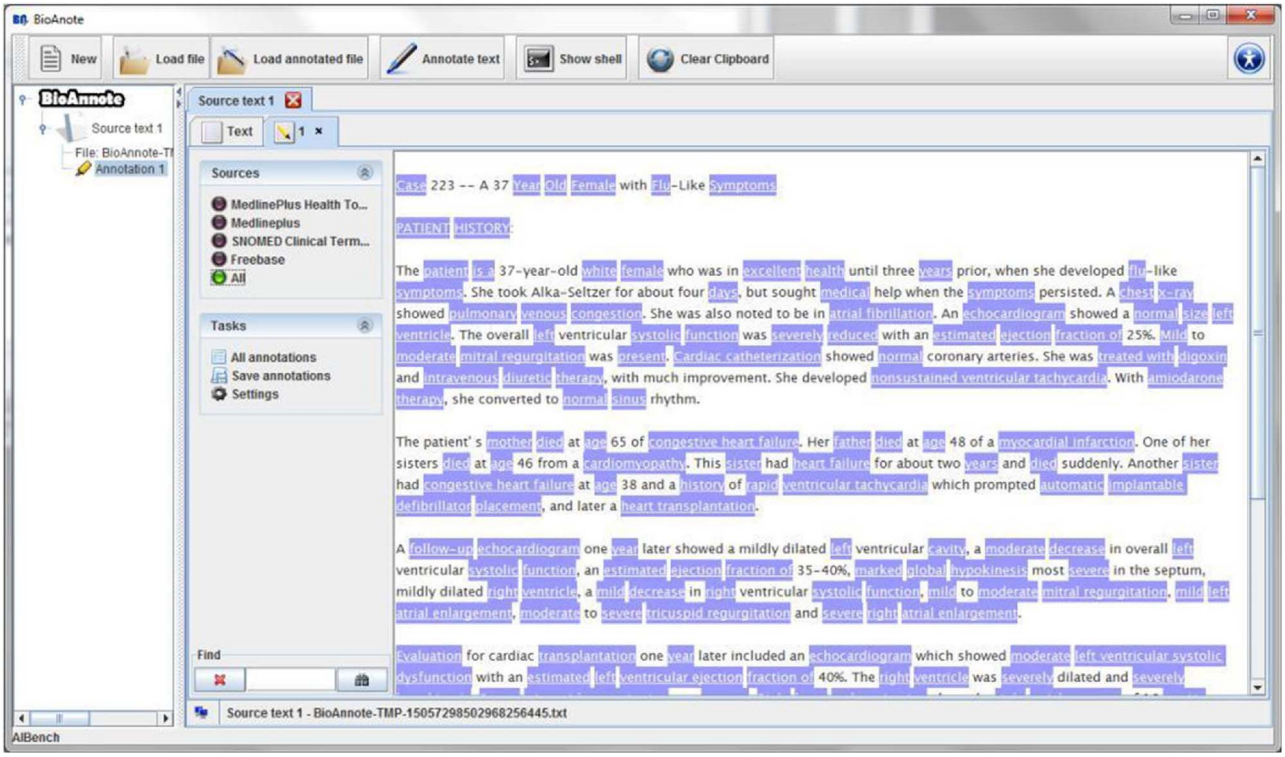

Fig. 1. BioAnnote system. (2-column fitting image).

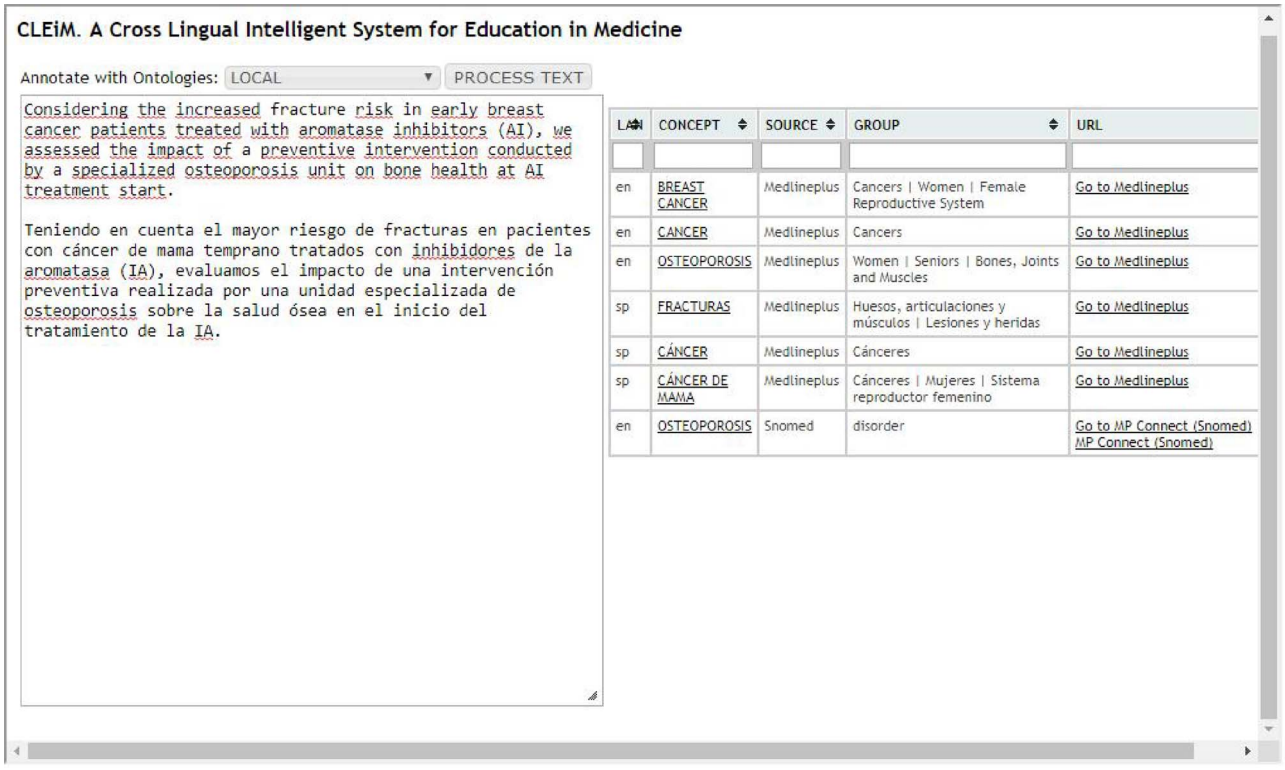

Fig. 2. CLEiM system. (2-column fitting image).

summarized the results in a table. A first version of this table was initially shared with the remaining members of the interviewer team, who checking the cells for errors or incomplete data in an iterative manner. Further analysis of the results also followed an iterative process.

2.6. Data analysis

The analysis of the data consisted of a quantitative analysis, or evaluation of the responses to quantitative questions, and a qualitative analysis, or thematic evaluation of the responses to qualitative questions.

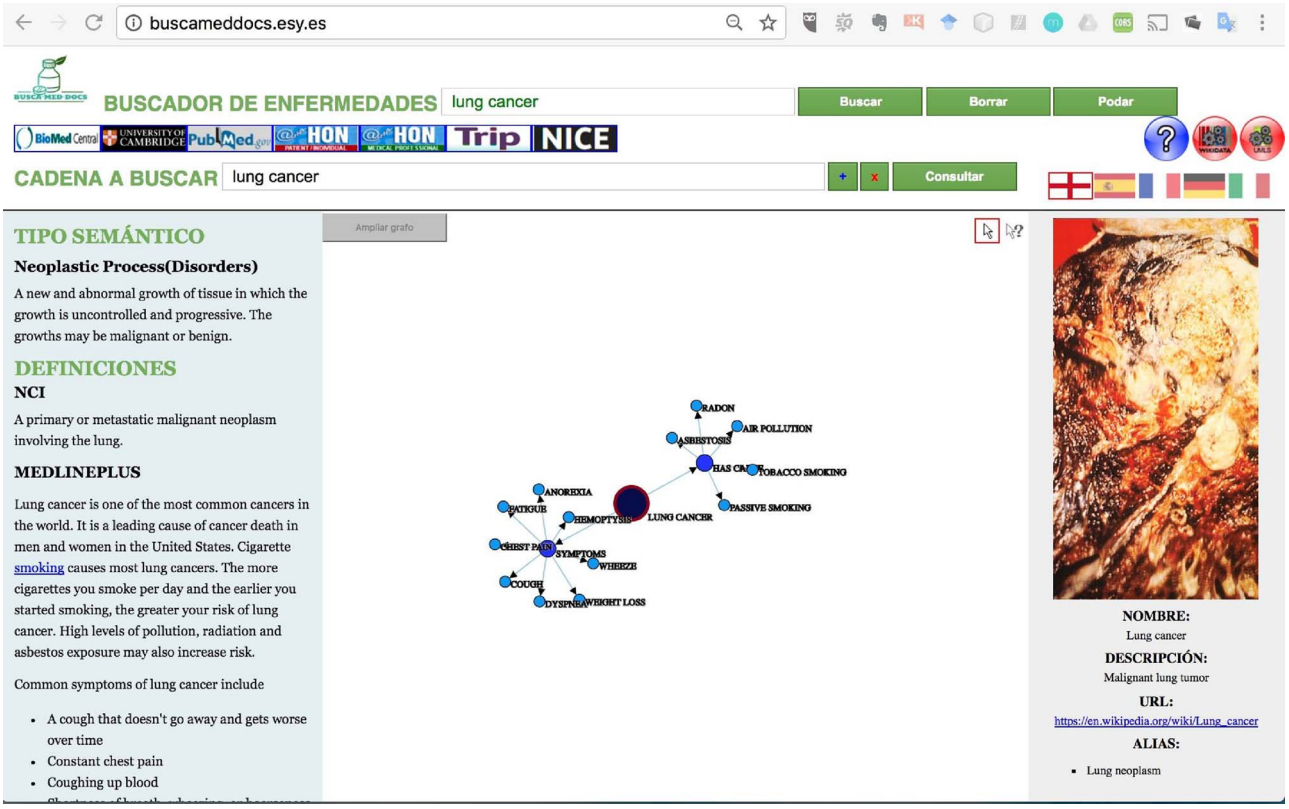

Fig. 3. MedCMap system. (2-column fitting image).

The first analysis was performed on each quantitative question belonging to each category in each block. The results from this analysis are presented in this format in the next section. For this task, we selected the mode and median as quantitative measures of the responses to Likert-type scale questions. In addition, we compared the respondents' perceptions of the BioAnnote, CLEiM and MedCMap systems.

The qualitative analysis involved extracting key themes (such us reliability of information sources, bilingualism and their usefulness as a study method) from the responses to the open-ended questions. The set of transcribed fragments are available in Appendix B, Appendix C and Appendix D, wherein each fragment is preceded by the corresponding respondent's identification code. Appendix B contains selected fragments concerning the use of annotation systems and the respondent's opinion of the BioAnnote system. Appendix C contains selected fragments from the same respondents regarding their use of the concept extraction systems and opinion of the CLEiM system. Finally, Appendix D contains selected fragments from general comments made regarding the construction of concept/mental maps and particular observations concerning MedCMap application.

3. Results & discussion

In this section, we present and discuss the results obtained following the structure described above, in which the responses to the 66 questions classified into 11 categories were finally analyzed. We summarize the information in 5 blocks focused on: (*i*) general information and knowledge of active learning methods (Section 3.1); (*ii*) knowledge related to concept annotation (Section 3.2); (*iii*) knowledge related to cross-lingual concept extraction (Section 3.3); (*iv*) knowledge related to conceptual or mental maps (Section 3.4); and (*v*) classification of the intelligent systems (Section 3.5). Additionally, Section 3.6 presents and discusses some key themes extracted from the open-ended questions.

3.1. Block 1: general information and knowledge of active learning methods

3.1.1. Category 1: personal information and background

In accordance with our methodological approach, we considered a sample of teachers with diverse profiles, including their background, subject area, teaching experience, age and sex. Of the 11 BS and HS teachers interviewed, 9 were women and 2 were men. The mean age of these teachers was 42.55 years. All taught degree classes at Faculty of BS, Faculty of HS or both. More detail of the responses to questions regarding to personal information and background are reported in Table 4.

Regarding the perceived English level by type of degree, the teachers' perceptions of the level of English proficiency among their students were high intermediate for medical students, and low intermediate for other types of student. These data are important for the

Table 4
Responses of the teachers to the questions of the category 1.

Question	Response
Sex	Male (n = 2)/Female (n = 9)
Age	30–52 years (42.55 ± 7.34)
Faculty/School	BS (n = 7), HS (n = 2), BS & HS (n = 2)
Subjects taught/Level of classes taught	Medicine (n = 6), Dentistry (n = 5), Physiotherapy (n = 4), Pharmacy, Optometry and Nursing (n = 1)
Years of teaching experience	2–24 years (10.36 ± 7.50)
What do you believe you level of English proficiency to be?	High (n = 4), Medium (n = 3), Intermediate-Low (n = 2), Low (n = 2)
What do you believe your students' average level of English proficiency to be?	High (n = 1), Medium (n = 3), Intermediate-Low (n = 5), Low (n = 2)
Computer knowledge (with clarification the meaning of these levels)	Advanced (n = 5), User (n = 6)

Table 5
Responses of the teachers to the questions of the category 2.

Question	Response
Do you use computers in the classroom?	Yes (n = 11)
How do you use the computers?	Mainly for prepare activities
Do you use active learning methods?	Yes (n = 11)
Which active learning methods do you use?	CBL (n = 3); discussion of clinical cases (n = 4); co-assessment and self-assessment (n = 1); puzzles (n = 1); Vademecum, anatomical atlas, literature searches and other uses (n = 4); more sophisticated software (n = 1)
What computer programs do you use to prepare activities?	Word processors (n = 6); Spreadsheets (n = 3); Internet searches (n = 3)
What programs do you use to carry out these activities in the classroom?	Word processors (n = 3); Spreadsheets (n = 1); Moodle (n = 2)
What programs do the students use while engaging in these activities?	Search engines, bibliographic websites and library resources (n = 4); Word processors (n = 3); Presentation software (n = 2); Moodle (n = 1; Statistical programs (n = 1)
What are the three most important web-based information sources you use in your teaching activities?	Pubmed (n = 6); Medline & Pubmed (n = 3); Ocenet & Elsevier (n = 2); others (n = 1)

development of cross-lingual systems as classroom learning aids and less important with respect to helping teachers prepare activities. Finally, be highlighting that none of the instructors considered himself/herself to possess an expert level of computer knowledge.

3.1.2. Category 2: information tools and sources of information used in the preparation or execution of active learning activities

A synthesis of the teachers' responses to the questions of this category, which are presented below, are reported in Table 5. All the teachers reported they used computers in some way in the classroom, mainly for projecting content during classes (for presentations, showing videos, use of the digital Blackboard and Internet searches). Although all reported using active learning methods (of very different types), only 1 used more sophisticated software (for statistical analysis) in the preparation and execution of activities. These results highlight the need to produce more user-friendly software for teachers and the need for training regarding the software's use. Two respondents reported using no specialized computer program (excluding Internet browsers) to prepare activities, of whom 1 had never used such software in the classroom (the other had only used the Google search tool). Most of the 9 interviewees who indicated that they did use computer programs for preparing learning activities also used these programs in the classroom (only three did not). All respondents cited the use of bibliographic resources for the preparation of activities. Fourteen Internet information sources were reported as being used during teaching activities. The most commonly used was PubMed/Medline (used by 64%); the use of other information sources, such as Ocenet or Elsevier, was far less prevalent (18%). Finally, the Dialnet, University of Delaware Faculty of Medicine, UEM digital library, Fisterra, CDC, OMS, Vademecum, Spanish or European Medicines Agency, Scopus, Sociedad Española de Microbiología and Francisco Soria Melguizo websites were mentioned by 1 teacher.

3.1.3. Category 3: CBL methods and use of case reports

All respondents knew what CBL was, and all but one used CBL in the classroom; of the remaining 10, 2 said they used it only occasionally. This type of activity, therefore, appeared to be used by many teachers of biomedical subjects. All of those who used CBL methods used case reports during the execution of these activities. These reports originated from several sources: written by the respondents themselves (6 out of 11), real-life case reports that they modified to meet the needs of the course (3 out of 11) and case reports from books, journals or the Internet (4 out of 11). The most used language for the case reports was Spanish (6 out of 11), although some respondents also used English (2 out of 11) and both languages (4 out of 11).

The descriptions of how these case reports were used in learning activities demonstrated the same general principles with slight procedural differences. One respondent used several case reports instead of a single report. All teachers made the reports available to their students so that they could prepare before class (via Internet o Moodle mainly). Only 4 mentioned including the use of case reports for student evaluation purposes. Six respondents said they discussed the case with the class following the activity. Thus, the lack of any standardization in terms of implementing such activities was noticeable.

3.1.4. Category 4: intelligent systems and NLP systems in the classroom

No respondent knew the meaning of the term "intelligent system". However, after being provided an explanation by one of the interviewers, 2 confirmed they used an intelligent system to prepare learning activities, and 3 (the latter 2 plus 1 more) said they used an intelligent system in the classroom with students. These systems included searching, with a concept in mind, for videos on YouTube, searching clinical practice guides, and student-performed Google searches.

Two respondents had a basic idea of what an NLP system was. However, after being provided an explanation by one of the interviewers about what a NLP system was, 4 respondents reported using NLP system (google translate and google search).

3.2. Block 2: knowledge related to concept annotation

3.2.1. Category 5: use of annotators

None of the respondents knew what an "intelligent system for concept annotation" was, and the instructors confirmed they were unaware of such systems even after one of the interviewers explained their characteristics. Naturally, therefore, none of the respondents had used one of these systems to either to prepare or execute learning activities. Most (10 out of 11) or all the respondents believed such a system would be useful when preparing and executing CBL activities respectively. However, two respondents thought this might prove difficult: one of these persons only observed such systems being of use to brighter students, and the other thought it made searching for information too easy for students (this teacher believed that searching for information to be an important part of learning in his/her course).

3.2.2. Category 6: opinions regarding the use of the BioAnnote annotation system in learning activities

After showing the respondents the BioAnnote system, the answers to the Likert-type scale questions showed that most believed that the system was useful during both the preparation (Q1 response) and execution (Q2 response) of learning activities. Both the mode and median values for the measure of the usefulness of the BioAnnote system in the preparation and execution of activities were 4 and 5, respectively, i.e., "Agree" and "Strongly Agree". The respondents' perceptions of the BioAnnote system are reported in Table 6.

Some additional comments regarding this system were made by some respondents following explanation of the system by the interviewer and after answering Q1 and Q2 (Table 6; see the fragments

Table 6
Subjective perceptions of the BioAnnote, CLEiM and MedCMap systems.

System	Statements	Answers					Mode	Median
		1 *Strongly Disagree*	**2** *Disagree*	**3** *Neutral*	**4** *Agree*	**5** *Strongly Agree*		
BioAnnote	Q1	1	0	1	5	4	4	4
	Q2	0	0	1	2	8	5	5
CLEiM	Q1	0	0	1	5	5	4–5	4
	Q2	0	0	0	3	8	5	5
MedCMap	Q1	0	0	3	2	6	5	5
	Q2	0	0	2	2	7	5	5

Q1. Do you think the system is useful for preparing CBL activities?.
Q2. Do you think the system is useful for executing CBL activities in the classroom?.

recorded for respondents 1–5 and 8 in Appendix B). Other respondents made comments during the explanation provided by the interviewer (see square brackets in the Appendices) regarding the characteristics of the system and the sources of information from which it derives information (see the fragments recorded for respondents 6–9 and 10–11 in Appendix B).

3.3. Block 3: knowledge related to cross-lingual concept extraction

3.3.1. Category 7:Use of monolingual and cross-lingual concept extraction systems

Beyond a certain intuition as to what a concept extraction system might be, none of the respondents was certain what the term "concept extraction system" meant. They had also never used such a system. Similarly, none of the respondent was familiar with cross-lingual systems. Following the explanation provided by the interviewer, all interviewees believed that such systems might be of use when preparing and executing learning activities.

3.3.2. Category 8: opinions regarding the use of the CLEiM cross-lingual concept extraction system in learning activities

The respondents' perceptions of the CLEiM system are reported in Table 6. The answers provided in response to the Likert-type scale questions suggested that the majority of participants agreed or strongly agreed with the usefulness of the system.

The respondents' comments regarding this type of system and the comments that respondent made after being shown the CLEiM system are in Appendix C.

3.4. Block 4: knowledge related to concept/mental maps

3.4.1. Category 9: use of concept/mental maps

Five respondents were familiar with concept/mental maps. Only 1 respondent knew of a tool that might help when executing activities based on concept/mental maps, specifically FreeMind [57], and had used it both for preparing and executing learning activities. Curiously, this respondent did not know what concept/mental maps were, and at first indicated that he/she did not know how they would be used. However, after being explained their nature, the respondent indicated that he/she had used something similar during tutorials (for explanatory rather than assessment purposes). All and the most of respondents (10 out of 11) indicated that such a tool would be useful to help them use mental maps in the classroom and for preparing such activities, respectively.

3.4.2. Category 10: opinions regarding the use of the MedCMap mental map system in learning activities

The respondents' perceptions of the MedCMap system are reported in Table 6. The answers provided in response to the Likert-type scale questions suggested that respondents mostly strongly agreed with the usefulness of the system.

Appendix D contains fragments from the transcriptions regarding the respondent's opinions of the use of concept/mental maps and the MedCMap system.

3.5. Block 5: arrangement of the examined IIA systems

3.5.1. Category 11: how would you order the systems evaluated herein in terms of their usefulness in teaching? (decreasing order by perceived usefulness)

A graphical representation of the classification of the three systems in terms of their perceived usefulness in teaching is shown in Fig. 4. The respondents' answers to this question showed that the most highly regarded system was CLEiM, while the least regarded system was BioAnnote.

From those results, we established a relationship between the responses to Q1 and Q2 questions (Table 6). Thus, despite the fact that higher mode and median scores were returned for the MedCMap system on both Q1 and Q2, more responses were clustered around the 4 and 5 mark for the BioAnnote and CLEiM systems. Both the median and mode values of the respondents' answers to the Q2 questions indicated that the respondents strongly agreed with the usefulness of all three assessed systems in the execution of activities.

Thus, the relatively small number of respondents who preferred the MedCMap system valued it very highly, while the other systems were perceived as more useful than MedCMap. Specifically, the cross-lingual features of the CLEiM system made it be selected by most of the respondents as the most useful of the three IIA systems evaluated.

3.6. Key themes extracted from the open-ended questions

(1) Our analysis of the fragments recorded in response to the open-ended questions (Appendices B, C and D) revealed a set of key

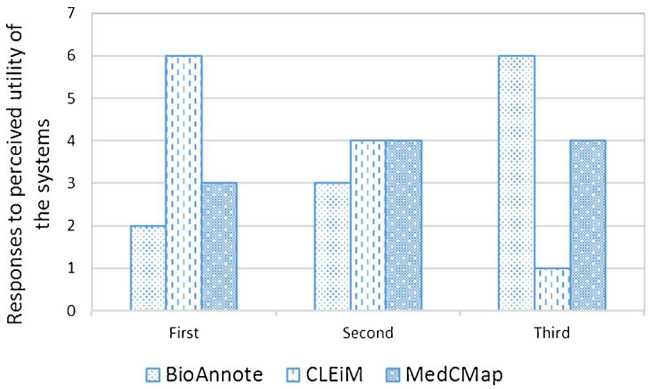

Fig. 4. Classification of the three systems (i.e., first, second and third place) by the respondents in terms of their perceived usefulness in teaching. The number that appears above the bar plots indicates the number of respondents who ranked each of the systems first (left), second (middle) and third (right). (single −column fitting image).

Table 7
Key themes extracted from the comment fragments made with respect to the BioAnnote, CLEiM and MedCMap systems.

System	Key themes	Interpretation	Respondent identification code
BioAnnote	Reliable sources	Several respondents mentioned the usefulness of the system regarding its use of reliable sources of information (i.e., in terms of the medical terminology used and bibliographic information) that was of good quality and demonstrated the required scientific rigor.	1, 2, 3, 6, 10
	Selective annotation	The ability of the teacher to determine the terms that the system should annotate was highly valued.	1, 2, 4, 9
	System drawbacks	The teachers believed that the system made searching for information too easy.	5, 10
	Usefulness as a medical glossary	The respondents indicated that the system may help increase comprehension of medical terms among first year students and non-medical teachers.	8, 11
	Usefulness for highlighting key concepts	One respondent commented on the usefulness of highlighting the most important concepts within a case report, allowing for increased comprehension.	7
CLEiM	Extension to other languages	The teachers believed the fact that the system could use languages other than English or Spanish to search for information to be useful.	1, 2
	Usefulness for foreign and less experienced students	The responses emphasized that the system could be useful to students whose Spanish is not perfect (the case of many foreign students) or who are beginning to familiarize themselves with such terminology (i.e., those in the lower years).	2, 3
	Stimulus for learning terminology in English	The respondents appreciated the bilingual nature of the system, which allowed for medical terms to be learned in English.	4, 5, 6, 7, 11
	Bilingual aid to teachers	One respondent indicated the potential usefulness of the system when working in groups who spoke both languages; the system would allow teachers to avoid having to prepare the activity in both languages.	8
MedCMap	Usefulness as a study method	Several respondents mentioned that the system might be useful as a study method and for summarizing content.	1, 3, 4
	Usefulness as an assessment system	The respondents believed that the system might be useful for self-assessment and formal testing of subject knowledge at the end of a course.	1, 3, 10
	Comprehending explanations in class	This system allows the teacher to make classes more active and the students to better comprehend the content presented.	1, 9
	Map format	The respondents indicated that the format of the map to be important and appreciated the possibility of having different presentation options. Suggestions were made in this respect.	2, 6, 7
	Difficulty of use	The respondents expressed doubts about the use of conceptual maps *per se*, suggesting potential technical failings of the system and the time required to learn to use it.	8, 10, 11

themes (Table 7) regarding the potential use of BioAnnote, CLEiM and MedCMap systems by the teachers. These key themes are listed in detail below:

(2) The most highlighted themes were (highlighted by 5 out of 11 respondent) the usefulness of BioAnnote system to provide reliable sources of medical information (rigorous medical terminology and quality bibliographic information) and the usefulness of the bilingual nature of CLEiM system for learning medical terminology in English.
(3) The following theme highlighted by the respondents (4 out of 11) was the selective annotation feature of BioAnnote system, which allowed teachers to select the terms that the system annotated.
(4) Three out of eleven respondents also highlighted themes respect to the MedCMap system, which were: (i) usefulness as study method and for summarizing content; (ii) usefulness as formal assessment method of subject knowledge at the end of a course; (iii) the map format feature of MedCMap system, as well as their different presentation options, were highlighted as a means of condensing information and for assessment, too and; (iv) difficulty of use, both for the difficulty of understanding conceptual maps and for the time required to learn to use the system.
(5) In addition to the previous key themes, 7 other themes were highlighted by a low number of the teachers (1 or 2 out of 11). However, as part of the qualitative study, it is interesting to take them into account. Therefore, these themes as well as their interpretation are also shown in Table 7.

4. Limitations

The outcomes of this work are circumscribed to the perceptions reported by a relatively small number of participants. Interviewing teachers with different backgrounds provided interesting and diverse data within the study but also may have contributed to an increase in the variability of their perceptions. Future studies should be conducted including a greater number of participants and other IIA systems in order to achieve greater generality of results.

The applications employed for assessing the general conceptualization and utility of IIA systems in the preparation and execution of learning activities were also associated with some limitations, such as the use of data limited sources and technical constraints. However, such applications encompassed the options offered on the web.

5. Implications

Despite the limitations mentioned in the previous section, this work showed that IIA systems that may aid in the processing of natural language texts could be very useful for improving current active learning platforms used for active learning activities, such as Moodle [58–60] or Blackboard [61,62]. In addition, they also provided a reliable source of information without requiring the separate use of Internet search resources.

6. Conclusions

In summary, this work describes the results of an analysis of the knowledge and perceptions of degree teachers about active learning methods and intelligent systems in general, as well as, the utility of three IIA systems, as effective tools in preparing and executing learning activities. Our results showed that few or none of the interviewees were familiar with technical terms related to the systems such as “intelligent systems” or “concept/mental maps”. However, they understood the potential utility of the BioAnnote, CLEiM and MedCMap systems, both in the preparation of activities and in their implementation in the classroom. In other words, this work showed that integration of reliable sources of information, bilingualism and selective annotation of concepts were the features most valued by the teachers, who also considered the incorporation of these IIA systems into learning activities to

be potentially very useful. Additionally, and taking into account our experimental conditions, this work highlights the utility to integrate IIA systems into active learning, and the results of this work also suggest some key themes to consider when developing these types of systems.

Conflicts of interest

None.

Author's contribution

All the authors contributed to the conception and design of the study. F.A. and M.B. performed the acquisition, analysis and interpretation of data, with contributions from M.R., A.H. and M.L.M.-B. H.L.-F., D.G., F.F.-R., M.V., M.M., F.A., R.M. and M.B. adapted the intelligent systems for the interviews. M.R., A.H. also provided their medical expertise. M.L.M.-B. wrote the manuscript with significant contributions from F.A. and M.B. Finally, all authors reviewed the final manuscript.

Summary points

What was already known on the topic?

- Data suggest that different types of intelligent information access (IIA) systems can be successfully applied in the educational system.
- However, there are few examples of the application of systems utilizing artificial intelligence techniques to solve practical problems in the active learning paradigm in higher education.
- IIA systems have already been shown to be useful in active learning, e.g., by improving student comprehension.
- Whether teachers could accept the use of these systems as a component of their course was unknown.

What this study added to our knowledge?

- We focused on the perceptions of teachers of biomedical subjects, which have not been frequently considered in previous research.
- The results of this study show that IIA systems that include the integration of reliable sources of information, concept extraction and bilingualism are valued by degree teachers, who also considered the incorporation of these systems into learning activities to be potentially very useful.
- Under our experimental conditions, our results suggest that IIA systems may be easily integrated in their curricula.
- The results of our study provide insights into the need to produce user-friendly IIA systems for teachers and the usefulness of such systems as a component of any existing learning platforms.

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Appendix A. Description of the questions for each category

Category 1**:** Personal information and background.

In this category, respondents were asked their sex, age, faculty or school in which they taught, subjects they taught, number of years of teaching experience, (subjective) level of English proficiency, students' perceived average level of English proficiency, and (subjective) level of computer knowledge. The answers to the last question were accompanied by clarifications on what the respondents meant by the levels they indicated.

Category 2: Information tools and sources of information used in the preparation or execution of active learning activities.

The questions were mainly open-ended to obtain information on the systems used by the teachers in the classroom and the manner in which they were used in active learning. The teachers were also asked which Internet information source they thought was the most important in their teaching.

Category 3: Case-based learning (CBL) methods and the use of case reports.

The aim of the questions in this category was to identify in greater detail the ways in which the respondents used CBL (if at all), the use of case reports in CBL activities, the origin of these case reports, and the language in which they were written. When the respondents were not familiar with this methodology, they were provided a previously prepared verbal description.

Category 4: Intelligent systems and natural language processing (NPL) systems in the classroom.

The questions in this category were designed to gather information on the respondents' knowledge of the three systems under assessment and to determine whether they used similar systems to prepare or execute learning activities in the classroom. When the respondents were unaware of such systems, they were provided with verbal descriptions.

Category 5: Use of annotators.

Category 7: Use of monolingual and cross-lingual concept extraction systems.

Category 9: Use of concept/mental maps.

In these three categories, the questions were designed with the aim of determining the respondents' level of knowledge in the aforementioned areas before being introduced to the systems under evaluation. After asking whether they understood the terms that defined these systems, the characteristics of the systems were explained to the respondents and introduced to them.

Category 6: Opinions regarding the use of the BioAnnote annotation system in learning activities.

Category 8: Opinions regarding the use of the CLEiM cross-lingual concept extraction system in learning activities.

Category 10: Opinions regarding the use of the MedCMap mental map system.

These three other categories included questions intended to evaluate the perceived usefulness of the three intelligent systems in preparing learning activities (Question Q1) and as a learning aid in the classroom (Question Q2) on a Likert scale. The respondents were asked about the three systems after being introduced to them.

Category 11: How would you order the systems presented in terms of their usefulness in teaching? (decreasing order)

After the interview, the respondents were asked "How would you order the systems presented in terms of their usefulness in teaching (decreasing order)". The aim of this question was to quantify the overall view of the usefulness of the presented systems.

Appendix B. Fragments of comments made regarding automatic annotation systems in general and BioAnnote in particular

(1) … it is very interesting that a case or article may be annotated with

one thing or another, depending on your needs… an activity could require 4 annotations, and the student would use them with supervised information sources… (this is) very clear, very clear…

(2) … an activity may be used to introduce the students to a text in the context of the subjects they are studying… I would like you to extract words that are applicable to… it would be great if the system were connected to the resources that are normally recommended to the students…

(3) … you can prevent them from looking for information in unreliable places… students commonly continue to use these unreliable resources even though you tell them not to… this way they also get used to using a more evidence-based references…

(4) … it would be interesting if you could apply different quantities of concepts depending on the students' knowledge… for those just starting, it would be good to apply less concepts and better orient their search; those with more experience could handle more underlining…

(5) … I do not need anything special to prepare for an activity… in my subject area, it is very important to deduce the meaning of some words from others… if the system provides me those words, it might be counter-productive… however, for more advanced students, it might be useful…

(6) … if a database such as Wikipedia is used… perhaps there is no medical filter…/[general explanation]/(this system may apply) a certain scientific rigor so that the students gain an understanding of an idea; that appears to be a very good idea

(7) … especially for orienting students at the beginning of a course… to call their attention to the things they need to be aware of and the things that are not important…/[general explanation]/…it is a good idea, the information is quite complete… however, they would need some understanding of the case before they looked at the results provided by the system… changing the format of an activity often keeps students interested

(8) … I seem to spend all day looking for the terms that the system annotates… I think it would be very useful for preparing activities… these words are not just of use to me, I can ask the students about them… I think the system is very good for preparing case reports and obtaining information about medical terms I have not used or do not recognize

(9) … does one have to introduce the text oneself?/[Yes]/How does the system know these terms?/[using sources considered important by medical experts]/it seems very interesting…

(10) … what allows the system to annotate these concepts and not others?/[on the sources included in the system… which were selected by a team of 2 physicians and 2 IT specialists…]/… it is good with respect to the references; we already know the terms prior to performing the activity; I think it is more interesting for the students… I think this would be good for students, but it makes things too easy for them… having to work less is a negative factor…and this type of searching also helps them to learn…

(11) … it could be good for keeping students on track when searching… I think the teacher would have to use it and see how it works and then use it with the students… the students would need some prior knowledge…/[general explanation]/… we have used something similar, not exactly the same, a pathology atlas via "Ocenet salud"…/[in that system you use concepts rather than complete texts, don't you?…]/… true, you use concepts… this system could be useful for researching… Does it search for information in the databases you mentioned?/[… exactly…]/… for the basic information, I think it is a good idea, especially for first year students… it would be very interesting if they could handle both basic and more complicated information… the system does not appear to be very intuitive… but I think it could be easily learned…

Appendix C. Fragments of comments made regarding cross-lingual concept extraction systems in general and CLEiM in particular

(1) … the system can be accessed in both English and Spanish; can it cross-reference other information?/[… it might be possible to include sources in other languages…]/… there are certain topics that you find in languages that hardly anyone speaks… for example, in Portuguese, there are some good studies in areas that interest me at the moment… or in Japanese, with respect to gastroenteritis… if the system could handle other languages, that would be really useful; there may be other tools that can provide the information for English and Spanish…

(2) … I think it would be of interest given the number of foreign students we have or if you want to improve your use of English…/[general explanation]/… Italian students, for example, could process the case in one language and obtain the information on their own… the system seems intuitive, you have the text and the concepts are identified in the system… and it extracts information that is relevant to the concepts… it is very good… it also provides visual information… the problem that I see is that the program performs the process that the student normally has to go through…/[… perhaps (it might be helpful) to find a more complex causal relationship…]/… of course, one could ask them to relate this information in a determined manner …

(3) … for basic courses, this would be very interesting, until the students gain an understanding of the basic terminology… so that they use the right translations…/[general explanation]/… it is good that it all appears on the same screen… this program is more user-friendly than the last program…

(4) … I think it (the system) is very useful, especially to teach students key words in English − that's key in making them take interest… it would be great to process case reports in English…/[… the system does allow you to do that…]/… this could provide a very powerful stimulus… it is perfect

(5) … I do not think the extraction of the concepts itself provides much additional value to the annotation, but the bilingual feature could be very useful… it could be useful for obtaining the right terms in English when preparing activities… even though I might know a word in English, I might not be sure of how to spell it…

(6) … I think it is interesting in both languages both in terms of activity preparation and when executing activities with students…

(7) … it would be helpful to help some students read…… some find this hard and this might help them… some words could be in English and others in Spanish…

(8) … since I work with groups containing both Spanish and English speakers, when I have a case report ready, it would be very useful to be able to get the information directly… since the majority of case reports are in English, the cross-lingual feature would likely be very good…

(9) … I can see how you use it, and its seems very good… you need to let me have a go myself…/[… in the test in which the students used the program they had no trouble even though they were given no instructions about how to use it…]/… maybe, but they were born with a computer in their hands!…

(10) … I think it is a great system; for the students, it is great because medical terminology is what they find most difficult…/[… the teacher with the tool can choose the information sources…]/… the trouble is that most just search using Google… I remember a test in which I asked them what a tumor is… but the best quality content does not come out… they find clinical cases very difficult… they find clinical cases harder to explain than they do the meanings of concepts… one has to interpret the information coming out − which is great for students…

(11) … it is good that it is in English − even better if it is in Spanish too, … for my students, who are older, it would be very good… it seems easy to use…

Appendix D. Fragments of comments made regarding systems for the construction of concept/mental maps in general and MedCMap in particular

(1) … similar to the annotation system, this looks important to me; the idea of using diagrams for learning is a good idea, e.g.,… I have used this as a method of explanation rather than as an activity/[… these activities can also be tested… a text would have to be prepared…]/it might be useful when reaching the end of a topic… after providing an explanation, they could make a map of the topic… I am going to use that idea you have given me…/[general explanation]/… students often start to study something and they get lost… I can see lots of applications for this, e.g., having a graphic tree available throughout the class so that students can contextualize the explanations provided…

(2) … it seems to be a system that you could use both to prepare and to

execute an activity… I think you could do it all on the Blackboard…/[… do you have any comments on its usability? Do you think it is intuitive? Could it be differently set out? Could it be used for other things?…]/perhaps the format would need to be changed a bit; it is a bit difficult to read because it is all grouped together/[… it can be moved…]/… for example, the explanatory circles should be adapted to the text…

(3) … it would be a useful tool for studying and class preparation…/[what about for students?]/… yes, for self-assessment…/[general explanation]/… I think it would be very useful as an activity at the end of a topic, or as a study aid for students… it would be a good idea to be able to link the concepts of the concept map with the descriptions so that you do not have to pass from one screen to another

(4) … it is a simplification, which may be acceptable for younger students…/[general explanation]/… it might be good for the student since they work well with visualizations… but I do not like it …

(5) … so, the system creates a mental map based on a symptom, disease or diagnosis, etc?…/[… no, the system does not create a mental map, the user does… the system provides a diagram that helps the user make one…]/… I see, similar to FreeMind…

(6) … it is very good; the only thing that worries me is that the knowledge base needs to be adequate… if is it correct and up to date, etc., then perfect… if it is not, it could create confusion for both the teacher and student… the design looks great… similar changes would also be necessary for the other systems shown previously…

(7) … this system seems as if it is really intended for preparing diagrams or presentations … for introducing graphical information… it is a bit like what you can do with presentation-making programs…

(8) … it seems interesting as well, but I would probably not use it as much… since I would have to become very familiar with what a mental map is… the other part of the application seems more useful… as things stand, I think the other program would be more useful to me

(9) … it is similar to preparing a class with three presentations that are closed but that you open up depending on what you want… that is probably what I like most for everyday use, it would make classes easier if they comprehend you, helping you leave things closed for the next day…

(10) … the main problem is what the outcome would be when the system stops working… suddenly, you would have 50 students with their hands up… and it freezes/[… in fact, in the first system, we showed solves the problem of having to address many users…]/… I have always had to take materials to class on paper just in case the 'virtual campus' system stops working. That is the worst thing that can occur during a classroom activity; if you can sort that out, it would be great… another positive thing would be if the system marked the activity automatically…

(11) … it almost appears to be a diagram…/[… exactly… it's similar to a diagram with semantic information… with relationships…]/… in any case, it is very good, it synthesizes the information…/[… the idea is for it to be used with case reports…]/… but these data have to be introduced…/[… what the system does, it does so automatically…]/… so, what I do with these data is up to me… it is OK; what worries me is that the output could be very broad and the student could get lost; the more to the point and easier, the better, especially for first year students… you also have to take into account the fact that this instrument makes life easier… students are normally saturated with work… for me to use it, I would have to learn how to use it first; I'd want that time invested to be worthwhile, i.e., that it would really help me prepare activities… it seems simple…

Appendix E. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ijmedinf.2017.12.016.

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