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Creation and Analysis of Technological Intelligence Reports as Educative Tool in Biomedical Engineering

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Abstract— **Identifying and analyzing quality information sources of technical information is a fundamental skill to create and maintain a technological intelligence system. In the present work, we propose the intentional training of undergraduate biomedical engineering students to create a simple technological intelligence report by analyzing scientific publications and patents. Computerized Maintenance Management Systems (CMMS) focused on the medical devices industry is proposed as the central topic, results suggest that the creation of technological intelligence report generates value to the undergraduate biomedical engineering students given them a tool to identify the impact of new technology in healthcare and medical devices.**

INTRODUCTION

Undergraduate Biomedical Engineering programs worldwide are transforming their traditional approach of acquiring knowledge to the modern educative process of developing professional competencies. Among the established set of competencies, the specific one, *"the broad education necessary for understanding the impact of engineering solutions on a global, economic, environment and societal context,"* have proved difficult to teach [1] [2]. The academic staff is before the challenge of engaging the student in the structured reflection of the healthcare industry's impact, the process of identifying actual solutions as a potential source for the creation of new disruptive technology, and the top-notch knowledge, just at the time their students have a narrow vision. Technological Intelligence Reports (TIR) have proved to be a valuable tool to acquire a global and profound picture of the state of the art of a specific technology. TIRs summarize the frontier knowledge and the intellectual property analysis worldwide as a snapshot of the current and next future in one area.

A. Technological Intelligence Report (TIR)

Technology intelligence is an essential tool in any innovative organization, including both government and private companies, allowing them to develop an awareness of technology threats and opportunities. Technology Intelligence uses objective data, not expert grading, as a fundamental data source [3]. These sources usually include patents or scientific literature, and the objective is to transform them into a base of knowledge for strategy-making and planning[4] .

Identifying and analyzing quality information sources of technical information is fundamental to creating and maintaining a technological intelligence system [5]. From a broad point of view, Common Technological Intelligence methods include publication frequency analysis, publication citation analysis, quantitative conference analysis, patent frequency analysis, patent citation analysis, S-curve analysis, benchmarking studies, portfolio analysis, Delphi studies, technology roadmap, among others [5] . Currently, emergent data analysis techniques as machine learning have improved the efficacy of the Intelligence Report creation process [6].

In the present study, we propose the intentional training of undergraduate biomedical engineering students to create a simple technological intelligence report by analyzing scientific publications and patents. This educative strategy aims to develop a structured capability to create knowledge from data sources; thus, they will create value in the medical devices and healthcare market. They will grow professionally and assess with a prospective analysis of the current and emerging technologies' real economic and social impact. We consider as a topic of study the Computerized Maintenance Management Systems (CMMS) focused on the medical devices industry.

B. Computerized Maintenance Management Systems (CMMS)

CMMS are common in today's industries and can bring many benefits, including increased productivity, reduced costs, and effective utilization of the assets in any manufacturing and service producer. According to WHO [7] , a CMMS is: "a software package that contains a computer database of information about an organization's maintenance operations". Medical technology in a healthcare facility needs to be managed and maintained; in a healthcare facility, the biomedical department is responsible for daily inspection checks and repairs, and for planning activities related to repairs and purchase of new technology [8]. Additionally, services from external companies need to be scheduled and managed by the department. Nowadays, all these activities can be managed using software programs (CMMS) [9], that make this process easier and faster for the biomedical department and improves the quality of service. Automatization provided by

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CMMS brings great benefits to the healthcare institutions, these benefits are greatly improved using artificial intelligence or AI [10]. It is precisely state of the art in the sector and the key to evaluating if a novel biomedical engineer can identify AI as the short future central tendency in this kind of system, additionally to describe its relevance for all biomedical engineering operations related to keeping accurate inventory and data records for medical equipment, including preventive, corrective and training, and their impact on facilitating cost planning, maintaining performance and extending useful life in a safe environment. The CMMS has become an important tool in health-care technology management, therefore is a good subject for a biomedical engineer that should have to use them, select, or develop them.

METHODOLOGY

A. Student sample selection

The educational experience was held during the clinical engineering course with 26 eighth-grade students of the biomedical engineering career at the Tecnologico de Monterrey, Campus Guadalajara (the largest private university in Mexico). These students were instructed to create a technological intelligence report to identify the effectiveness of the CMMS, the scientific evidence based on indexed scientific journal information, and the state of the art searching in some patent databases. The group of students was trained to search and analyze scientific papers and the main topics on Intellectual Property and patent searching and analysis. Extra material with examples was distributed. Four teams were formed, the complete activity from the trainee to the evaluation lasted five weeks.

B. Students Training on database searching for scientific information and tools

The training stage involves two sessions to cover the following main points:1 definition of scientific document differences with non-scientific material. 2. Identification of the basic structure of a scientific paper Introduction, Methods, Results and Discussion, and Conclusion, the following questions are presented as a guide to identifying these components [11]: What question of the research was asked?, How was it studied?, What was found? What do the findings mean? 3. Identification of types of papers considering among others Original Articles, Case Report, Technical note, Review, Editorial, Letter to the editor, etcetera. 4. Use of open-access information sources and university resources. 5 Metrics to evaluate a journal, paper, and author as H-index and Scopus metrics (quartiles).

C. Students Training on Intellectual Property basic concepts and tools

The training stage involves two sessions to cover the following main points: 1. Learn the definition of intellectual property (IP), the main types of intellectual property that can be protected (industrial property and copyrights) and understand that a product or service can have several forms of protection. 2. Comprehend how inventions can be protected (patents, utility models, and industrial designs) and identify the characteristics of each type of protection (requirements, the term of protection, the process to apply for a patent in Mexico and abroad). 3. Through a guided exercise, the students use some databases to search for patents (Google Patents, Espacenet, Patentscope) and analyze the different parts of a document of a patent application or a patent granted. 4. Finally, the students identify the key elements to search for patents including keywords, the use of boolean operators and the international patent classification. With these elements, the students obtain a basic report of technology using free databases like Patent Inspiration, Patentscope and Google Patents.

The desirable outcome of this training stage is the student's awareness that scientific papers and patent searching is an iterative process that requires practice to find documents that are relevant to the search and the ability to interpret the significance of the paper and patent search findings. The quality of the TIR will improve as students developed their ability to search and analyze the information and the access to private patent databases that help to consolidate the information of public databases. The first step in this process required to identify the purpose of the search, for example for innovation trends, find how a technical problem is being solved, identify the patentability of an invention, and as a second phase is necessary to find the right keywords and related terms or synonyms that best describe what the search is looking for. In papers and patents search, it is highly recommended to search using connectors (and, or, not) or specials search symbols (*, "") to narrow or broaden the results. An advanced patent search, besides including keywords, inventors, or companies, also adds classification terms like International Patent Classification (IPC) to find out results in a specific technology field. Additionally, a deeper analysis requires analyzing the bibliographic information, abstract, figures, description and claims of the invention to find out the relevant patents for the search. Finally, structuring the results and the desired outcome in the creation of a report that includes general information like the data based consulted and the key terms used and mainly the information relating with the key actors (authors, universities, inventors, applicant, or assignee), the citation numbers for papers or patents filed or granted per year for intellectual properties, the places where the patent is protected, and the IPC terms related with the search. Considering these relevant aspects, we propose a sequence to create a simple TIR, fulfillment of the steps results in straightforward but competitive TIR, the deliverable we asked students.

D. Deliverable Structure (Simple TIR)

The creation of the TIR was described step by step according to the following:

Step 1. Creation of the relevant paper's database. Limit the search to 2010-2020 period (at least 15 papers), report the following information: consulted databases (SCOPUS, ScienceDirect, Google Scholar, IEExplore, Scielo, etcetera), used keywords including the relational/logical expressions, for instance: "artificial intelligence AND CMMS," "Machine Learning OR Artificial Intelligence AND healthcare.". Register the Journal´s information: Title of the paper, Journal

title and Authors, university of adscriptions, Quartile Range and H-index of the Journal, abstract, main result, and conclusions.

Step 2. Debug the paper's database. Exclude from the database duplicate papers, or irrelevant papers. Possible exclusion criteria: sources with intricate technical information or broad relate without focus to the main topic. Explain in the report. Rank the abstract list and select your final list of ten journals.

Step 3. Analyze the paper's database. From the debugged database, create a table with the following information: Published articles per year (from 2010-2020), Create a graph including the accumulative citations per year (considering the ten papers). Include in the report the top three affiliations, the top three countries, and the top three cited documents, and create a summary of the main findings.

Step 4. Creation of the patent database. Create a database of patents, limit the search to 2010-2020 (at least 15 patents). Report the following information: consulted databases (WIPO, ESPACENET, Google patents, etcetera), used keywords, include the relational/logical expressions, patents information: title, abstract, claims, applicant name, inventor name, application date, application number, WIPO publication number when applicable.

Step 5. Debug the patent database. Exclude from the database, no relevant patents. Possible exclusion criteria: patents with intricate technical information or without the focus on the industry area. Rank the abstract list and select the final list of ten patents.

Step 6. Analyze the patents database. From the debugged patent database, create a table with the following information: Number patents submitted by year (2010-2020), list of top inventors, top patent owners, and top countries. Analyze the claims in the top five patent list, extract three remarkable claims, related to the area.

Step 7. Report and Infographics. Besides the written report covering previous steps, an infographic must be created considering the most relevant information including in graphical presentation (tables, diagrams, etcetera).

E. Survey Application

Students were surveyed to determine the impact of the implementation of this type of report on the subject. The survey is made up of the following seven questions: 1. What is a technological intelligence report? 2. What sources of information should be consulted to generate a technological intelligence report? 3. Do you consider it valuable to know the structure and methodology of a technological intelligence report for your professional and / or academic activities? 4. In which situations would you use this kind of report? 5. On a scale from 1 (worst) to 10 (better), What is the level of expertise you consider you have acquired after the course? 6. Identify the elements that a technological intelligence report should contain regarding academic articles. 7 Identify the elements that a technological intelligence report should contain regarding patents.

RESULTS AND DISCUSSION

A. Reports analysis

The students ' teams created four reports and respective infographics, every with a complete structure, following the step guide. An infographic summary and a video report were also delivered. Figure 1 illustrates an example of one of the reports; relevant patent owners and patent inventors were presented as word clouds. Figure 2 illustrates an example of a different report summarizing the findings related to the created papers and patent databases. These reports were evaluated by two different professors considering a specific rubric. The rubric allows us to identify the step guide fulfillment. After this evaluation process, a deeper analysis was carried out to determine the quality of the recovered information in each report. Table 1 summarizes the relevant findings of the analysis for paper and patent database information.

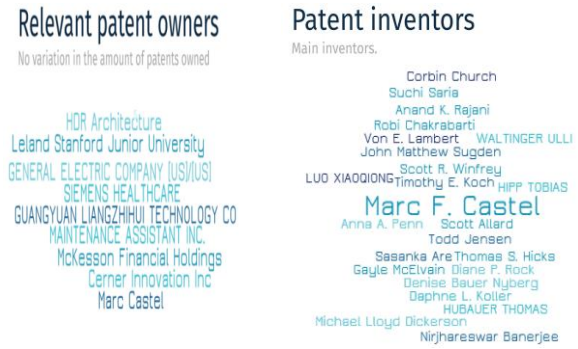

Figure 1. Example of information presented in the infographic summary relevant patent owners and patent inventors.

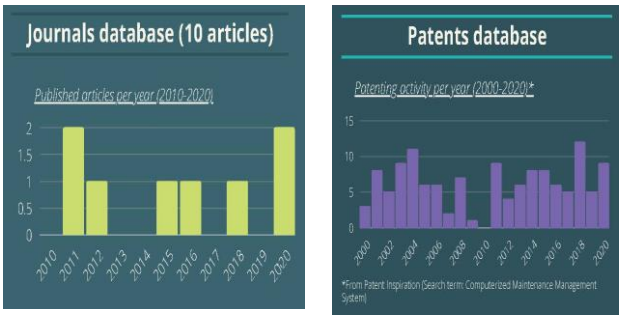

Figure 2. Example of information presented in the infographic summary, selected articles published by year and patent activity per year for CMMS topic.

As can be observed from Table 1, some of the flaws in the report are related to lack of experience. To obtain better results in the TIR elaboration, more than one revision of the information is required. This will allow us to unify criteria among the evaluator and the students, allowing us to refine the search and improve training.

B Survey Results

We collected six answered surveys (20 % of students). The survey results show that 100% know how to explain what a technological intelligence report is, and when defining it, the most important words they mentioned were: patents, scientific advances, intellectual property, and technology. Additionally, 83% fully identified the sources of information to generate this type of report, and 100% identified the elements that this type of report should contain; this is academic articles and patents.

For question number three, students ranked an average value of 8.6 for knowing the structure and methodology. Moreover, for question number five, students evaluated an average of 7.3 for the level of expertise. Figure 3 shows the distribution of the answers for question number four of the survey. The most mentioned activity where students considered a TIR useful was acquiring new technology; the less mentioned was the professional technical advisor. The rest of the answers received the same number mentioned.

TABLE I. RELEVANT ANALYSIS OF PAPERS AND PATENTS DATABASE INFORMATION

Scientific papers database	Patent papers database
• None of the reports include a definition of Computerized Maintenance Management Systems (CMMS). • Two of four reports mention the search strategy (keywords used and databases consulted) widely and specifically. • All of them include abstract information, main results, and conclusions. • They describe database debugging strategy but, some articles were duplicated; on some occasions, they reject a paper supporting the concept that CMMS positively. • They include a relevant number of papers related to artificial intelligence in the top list, but they were not related to the CMMS application. • They include the quartile metric but not H-index.	• The consulted database is always included. • Search strategy is included, this was focused on machine learning and artificial intelligence terms, but without the same emphasis to the CMMS concept. • They included the relevant information encompassing claims, application, inventor, and place of protection. • Number of found patents do not match to a simple search using the same keywords. • The use of logical operators was deficient in all reports.

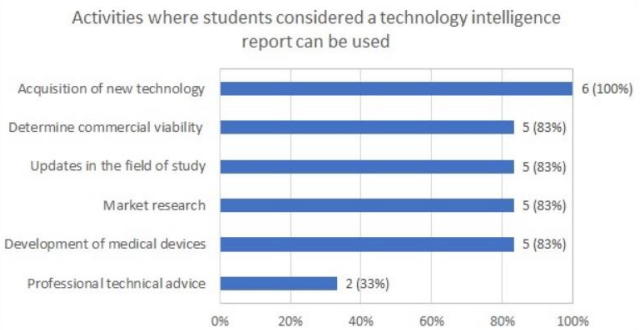

Figure 3. Results for question four of the survey: In which situations would you use this kind of report.?

Most students correctly identify the situations where a report of this type can be used, however, results also show that some students incorrectly relate the use of the report for market research rather than professional technical advice. Even though only 20% of the students answered the survey, the results show some relevant insights, it is identified that a technological intelligence report is a valuable tool for their professional and / or academic life. The results also show some points that need to be improved in the process and that will be implemented in the next generations.

CONCLUSION

We suggest the use of technological intelligence reports as analytical tools to generate value in the decision-making process. It is necessary to carry out several reviews at the end of the search and analyze information to refine anything or little relevant. A TIR will be valuable if the instructions are oriented to quality information sources, as could be observed in the specific case of the absence of the H index. Likewise, it is essential to unify the search criteria, to carry out several reviews in order for the evaluators to analyze the findings. To define rubric or definitive instructions that allow the student to obtain better results. Additionally, it is recommended to use this type of report as a didactic tool on courses where the student participates in the development of medical technology; in this way, the student will improve their competencies and get a better learning experience during their formation as a biomedical engineer.

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