Breaking the boundaries: academic applications of multidisciplinary research in computer science and dentistry

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ABSTRACT

Undergrad students are trained on a specific set of skills matching their corresponding careers, as modern sciences trend to specialization; however, it has promoted the creation of a virtual boundary among different professions. In this regard, state-of-the-art dental research involves the application of ever-increasing complex computational solutions; thus, requiring of multidisciplinary research teams. Multidisciplinarity is often achieved on a higher research context (e.g., postgrad); but involves a high degree of difficulty for both factions. The aim of this work is to present a novel application of multidisciplinary research to the learning process of undergrad students in computer sciences and dentistry careers. In order to do so, we leveraged previous research on computational intelligence and image processing techniques applied to dental diagnosis, and integrated it with the clinical assessment and software engineering subjects on dental and computer engineering careers correspondently. With this, we explored the possibility to enhance diagnosis skills of dental students, while improving the software engineering skills of computer sciences students; furthermore, we intended to introduce the concepts of applied computational intelligence, multidisciplinarity, and collaboration on both sides.

Keywords: Multidisciplinarity, Higher Education, Computer Sciences, Dentistry, Computer-aided diagnosis.

1. INTRODUCTION

The improvement of higher education has been a central part of the development strategies of most countries; which has leaded to a significant increase in student enrolment and graduated professionals across developing countries in recent years [1], [2]. Nonetheless, the emphasis of these strategies has also been controversial, because cognitive skills and professional competences are more related to economic growth rather than the amount of people graduating from Universities [3]. Within this context, it is possible to sustain that quality is preferred over quantity, e.g.: a specialized physician that has been highly trained in neurosurgery would certainly be the most qualified to perform an operation to the brain. Therefore, it is no news that the current trend in higher education is the promotion of technical skills over general ones, this is, pursuing specialization [4].

However, there is a widespread misunderstanding about the concept of quality in higher education. Effective teaching in higher education in one of the current challenges of modern society, where the best way to get students to conclude that it makes sense to pursue knowledge is where professors are intrinsically motivated to learn; thus leveraging original scientific research where both professors and students participate actively [5]. Learning is a multidimensional activity, which includes knowledge and abilities as well as values, attitudes, and habits of the mind [6]; therefore, encasing higher education curricula within a hard set of skills may be detrimental on the long run as some aspects of the formation are set aside, thus forcing students to learn them on their own when needed.

On the other hand, the issue of integrating the learning process to the everyday life and real-world problems is paramount. If we consider the previous example of the physician specialized in neurosurgery, it is also clear to us that modern medical advancements could only be achieved by the sum of the knowledge of multiple disciplines (e.g. mathematics, mechanics, biology, electronics, chemistry, informatics, psychology, etc.); therefore, inevitably requiring a cross-disciplinary approach. This dichotomy between specialization and generalization has been around for a while, and it is not an easy problem to solve, because it is possible to provide sound arguments to sustain both points of view.

It is interesting to notice that a major trend in the business world is to favour multidisciplinarity and generalization. The enormous success of companies such as Google® and Microsoft® is, in a considerable share, based on their ability to understand real-life challenges and integrate multiple disciplines to provide highly advanced technical solutions. Many authors have pointed out that innovation generated from multidisciplinarity has proved to be the key factor of the economic growth of developed nations [7], [8]. Conversely, educational systems of developing countries have been put under pressure by career specialization approaches, forcing them to utilize resources in the most efficient way [3]; but evidence show that these approaches have not demonstrated significant impacts on overall scientific and economical outcomes [4]. Consequently, we argue that generalist formation is exceedingly important for the advancement of science and economic growth, especially in developing countries.

In this regard, one of the disciplines that has been receiving special attention of the publics in recent years is Dentistry. Academic, economic, and scientific reports show that the number of dentists in developing countries has risen in the past 20 years, mainly because it is considered a high-income profession [2]. Furthermore, dental research has exhibited a significant improvement in recent years thanks to the involvement of technological solutions such as digital imaging, computer assisted diagnosis, computer assisted design and manufacturing, composite materials design, cellular engineering, and tissue regeneration. Multidisciplinarity has been essential to these developments; but multidisciplinarity in dental education is often achieved on a higher research context such as postgrad and commercial initiatives. The traditional delivery style that presents basic and clinical sciences information to undergrad students in dental schools has been primarily the lecture format, leading to a clinical rehearsal [9]. The concepts of research and multidisciplinarity are relegated to a second plane, reserved only to those individuals that intend to become full-time researchers or academics, as the vast majority of dentists pursue a clinical-practice approach [10]. This behaviour is understandable, essentially because dentists are highly-specialized physicians of the oral cavity, trained on a very specific set of skills.

In our modern society people expect dentist to solve a number of oral health problems related to pain, aesthetics, and function; all within the lapse of a few minutes. It is the equivalent of racing cars entering the pits for fast maintenance. Dentists are trained to deal with almost every oral health problem using their own hands; therefore, hundreds of hours of practice are needed to perform these feats. Nonetheless, these would not possible if not for the usage of state-of-the-art technologies. Dentists are encouraged to buy new devices and materials constantly, but the involvement of dental schools in the development of these new technologies is very limited. Innovation in dental technologies can be resource-intensive and highly time-consuming, thus making it even more difficult to perform in developing countries.

We explored the possibility to present the notions computer aided diagnosis of dental diseases to the students of the Dentistry Faculty of the University of Guayaquil (Ecuador). In this regard, computer aided diagnosis is one of the most challenging problems within both biomedical and computational sciences contexts, taking into account components of digital image processing, computational intelligence, biomedical semiology, clinical planning, among others. With this, we expected to enhance diagnosis skills of dental students while introducing the concepts of applied computational intelligence, image-processing, and cross-disciplinary collaboration. In order to do so, we leveraged a previous research project performed in the Dept. of Languages and Computer Sciences of the University of Malaga (Spain) consisting of automatic classification of dental tissues in different levels of disease using computational intelligence and image processing techniques [11]. Furthermore, we also explored the possibility to integrate computational sciences students of the University of Malaga with cross-disciplinary work teams, pointing to generate experiences with real-life application problems.

The aim of this work is to present a novel application of multidisciplinary research to the learning process of undergrad students in computer sciences and dentistry careers. The rest of this papers is organized as follows: the applied methodology is detailed in section 2; the results of the proposed approach are presented in section 3; the discussions and conclusion of the present study are presented in section 4; and finally the bibliographic references of this work are listed in section 5.

2. METHODOLOGY

The overall design of this cross-disciplinary collaboration study is presented in Figure 1. A total of 200 students from the Dentistry Faculty of the University of Guayaquil and 64 students from the Higher School of Informatics of the University of Malaga were recruited for this study. Dentistry students were divided in four groups, consisting of 50 students each; while engineering students were divided in two groups consisting of 32 students each. Students from both centres participated in the extension of a cross-disciplinary research project, receiving feedback of the progress obtained during each session, while guided by a multidisciplinary research team.

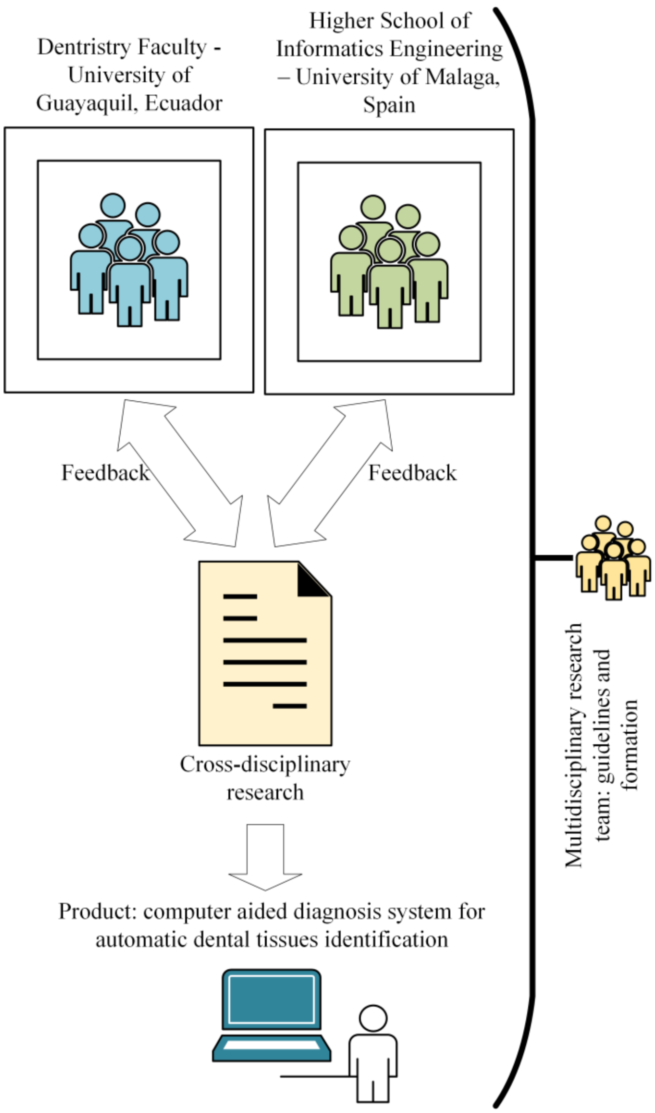

Fig. 1. Overall design of the study.

Scheduling

The presented methodology was constructed in order to provide fast feedback from alumni, teachers, and researchers involved in the two centres, while diminishing the weight of differences in disciplines and locations. In order to do so, this study had to be accommodated to the academic calendars of both centres; therefore, it was performed during the lapse of April and May of 2016. Additionally, lecture and workshop sessions were distributed weekly with the intention of providing enough time for both centres to integrate the feedback on each session.

Previous research integration

Alumni from both centres were presented with the basic outlines of a research comprising automatic classification of dental tissues in different levels of disease using computational intelligence and image processing techniques. This research had been executed in collaboration of both centres in the year 2014 within the scope of a large study [11]. The aim was to develop a computer aided diagnosis system for accurate and fast identification of different kinds of dental tissues; performed by a four-step process consisting of: image acquisition, region segmentation, feature extraction and tissue classification, as shown in Figure 2. Digital images of dental pieces were captured using macro photography techniques. Images were segmented using the Mean Shift algorithm [12]. Then, a set of features from the image pixels were computed from each segmented region as the mean and variance of the pixel values from each channel of the RGB, LUV, HSI, and Normalized RGB colour spaces. Features extracted from histogram analysis were: the two highest peaks after a moving-average filter [13]; the variance; the skewness; the energy; and the entropy [14]. Texture features were computed using a fourth order Daubechies wavelet function filter applied to each one of the RGB colour components, and the energy per element was computed for each sub-band resulting from the wavelet filtering process [11], [13].

Features extracted from each segmented region were then used as inputs for an Artificial Neural-Network classifier [15]. In the original work, outputs were selected by a team of five clinical dentists in order to train the classifier; however, the software suit designed for this task was very limited. This component was crucial, as it was later used as a powerful method for teaching dental pathologies of different tissues to dentistry students; and provided an excellent case of a real-world software engineering problem.

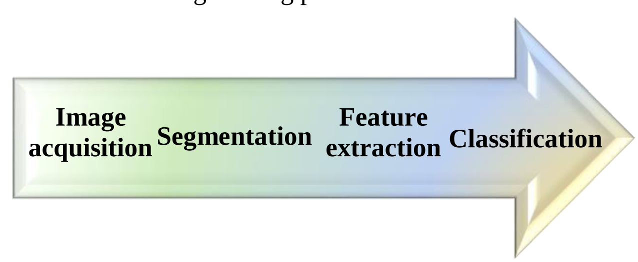

Fig. 2. Automatic image processing and classification steps.

Information delivery and feedback

The formative approach for engineering students is summarized in Figure 3: first, an oral lecture was given, followed by a round of questions. On a second session, students were instructed to perform an interview rehearsal to one of the dentist involved in the computer assisted diagnosis research project, with the aim of confronting them with a real-world case of cross-disciplinary teams. During the interview, students were required to identify the key factors of the research project, i.e.: objectives, biomedical research methodology, ethical guidelines, privacy of information, population involved, biomedical and dental lexicon, and the requirements of the computational systems involved. At the end of the session, students were asked to develop a mock-up application that would satisfy the necessities presented by the dentist expert and the proposed system. Finally, on a third session, engineering students performed a brainstorm while presenting the various mock-up applications; with this, it was possible to stablish well-designed guidelines for the development of a new application that would fit the necessities presented during the challenge. These guidelines were recorded and further used as the basis of examples and in-class workshops for the Software Engineering course.

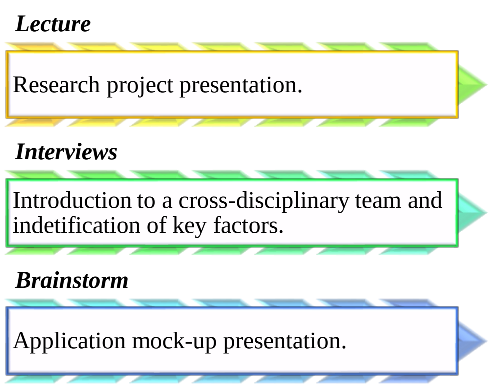

Fig. 3. Summary of the formative approach for Informatics Engineering students.

In a similar fashion, the formative approach for dentistry students is summarized in Figure 4: first, an oral lecture was given, followed by a round of questions. On a second session, students were directed to reproduce the training of the system's dental tissue classifier using the originally provided tool; the task was to actively identify dental tissues in the corresponding segmented regions of digital, images intended for training the supervised classifier. Furthermore, students were asked to detail all the difficulties and problems they may found by using the tool. This information was then communicated to the Informatics team in order to be used during their interview sessions. Finally, on a third session, dentistry students were presented with a revised application, constructed by following the guidelines recorded during the brainstorm sessions of Informatics students. This enhanced tool was used as an aid during clinical diagnosis of real patients as part of the regular training exercises of students.

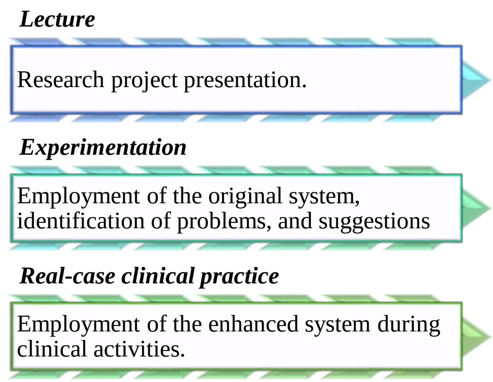

Fig. 4. Summary of the formative approach for Dentistry students.

The ability to correctly identify dental tissues was recorded. In order to do so a simple test was performed on all students after each of the three sessions. The test consisted on identifying the corresponding tissue to 10 randomly selected regions of a set of digital images that had been previously verified by a group of experts, and used for calibrating the original image processing system. The null hypothesis that there was no difference between the mean score obtained by students on the tissue identification task, taking into account the session number as the fixed factor, was evaluated with ANOVA (α=0.05), corrected with post hoc Bonferroni. This information was used as an indicator of the applicability of the methodology presented in this paper as a way of improving the clinical diagnostics abilities of dental students.

3. RESULTS

The execution of the proposed methodology required a total of 6 sessions for the Informatics Engineering faculty (2 groups, 3 sessions per group), and a total of 12 sessions for the Dentistry faculty (4 groups, 3 sessions per group); thus requiring a combined total of 18 sessions (approximately 26 working hours). Additionally, no special resources were needed for this study.

A total of 19 applications mock-ups were analysed, featuring a large range of novel functionalities, which leaded to the development of a final version of the original system. A novel set of case-studies of the different challenges encountered during interviews and brainstorm sessions was gathered as well.

On the other hand, feedback originating from experimentation and real-case clinical practice sessions accounted for at least 24 registered changes in the overall architecture of the original software.

Overall resulting scores per session measuring the ability to correctly identify dental tissues is presented in Table 1. Measurements were verified for normality (Kolmogorov-Smirnov test) and homoscedasticity (Bartlett's test). ANOVA test concluded that there were significant differences in the mean scores among sessions ($p < 0.0001$), verified with post hoc Bonferroni ($p < 0.001$ in all cases).

Table 1. Overall scores per session measuring the ability of the dentistry students to correctly identify dental tissues.

	Session 1	Session 2	Session 3
Mean	4.21	6.78	8.97
Std. deviation	2.32	3.11	3.77
Mode	4	6	8

4. DISCUSSION AND CONCLUSIONS

In this paper a novel application of multidisciplinary research to the learning process of undergrad students in computer sciences and dentistry careers was presented, relying on the coordinated efforts of different institutions.

The execution of the present study was considerably fast, taking into account the distance between institutions, and the differences between the disciplines involved. We consider this a sign of success. Results show that substantial goals were obtained during the lapse of three sessions, demonstrating the capabilities of students to work in real-world problems, and indicating a strong motivation for the project. Furthermore, results show that the diagnostic abilities of dental students improved significantly over a short period of time while participating in the development of the computer aided diagnosis system. Finally, the original computer aided diagnosis application was considerably enhanced with this work. It is interesting to notice that many of the students considered this to be one of their first experiences working with cross-disciplinary teams, working on real-world problems, and participating in an innovation project.

For all of these we conclude that that multidisciplinary research for joint innovation in dental and computer sciences is a strong and viable approach in the formation of undergrad students of both careers. Therefore, we strongly suggest that these efforts must be encouraged during the formative period of university students.

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