Development of Diagnostic Skills in Dentistry Students using Gamified Virtual Patients

Sneyder J. Sanchez M.[1], Juan E. Gómez-Morantes[1,*], Carlos Parra[1], Angela Carrillo-Ramos[1], Adriana I. Camacho[2] and Gloria C. Moreno[2]

[1] *Systems Engineering Department, Pontificia Universidad Javeriana, Bogotá, Colombia*

[2] *Dental System Department, Pontificia Universidad Javeriana, Bogotá, Colombia*

Keywords: Virtual Patients, Serious Games, Dentistry Education, Endodontics, Diagnostic Skills.

Abstract: The use of serious games, virtual patients, and other forms of digital learning technologies are starting to emerge in dentistry schools around the world. However, because of their novelty, there is still a need for literature discussing the different challenges of computer-supported education in this field. This paper presents the design, development, and pilot validation of a serious game for the development of diagnostic skills in dentistry students. Called RealTeeth, this game puts the student in a job interview context and asks him to diagnose 10 endondontic cases. Each case allows the student to follow 5 different diagnostic routes with different information and resources. At the end of the 10 cases, the student will receive a job offer in accordance with his or her performance on the cases. This game was tested with a cohort of student of the pre-clinic course of endodontics in the Pontificia Universidad Javeriana in Bogotá, Colombia. The results of this pilot validation were positive in terms of user acceptance and attitude, reinforcing the potential of computer supported education in the field of dentistry.

1 INTRODUCTION

Endodontics is a dentistry specialty that focuses on the study of dental pulp and dental pulp diseases.

In the case of the Pontificia Universidad Javeriana, endodontics is taught as part of the dentistry undergraduate program with two obligatory pre-clinic courses[1] and one emphasis course[2]. The two pre-clinic courses are seen in the third year of the five-year dentistry program, while the emphasis course is seen in the fourth or fifth year of the program.

The three endodontics courses are structured following Miller's pyramid (see Figure 1). The first course is dedicated to what Miller calls knowledge assessment, understood as "some assurance that a student, a resident, a physician *knows* what is required in order to carry out those professional functions effectively" (Miller, 1990, p. S63, emphasis in original). For endodontics this includes all the knowledge related to tooth and dental pulp anatomy, endodontics conditions (the 11 basic diagnosis[3]), the signs of the 11 basic diagnosis, and the tests needed to reach any of the 11 diagnosis.

The second course is aimed at the competence assessment level of Miller's pyramid, defined as the one that evaluates that "graduates must also *know how* to use the knowledge they have accumulated" (Miller, 1990, p. S63, emphasis in original), and is devoted to semiotic competences.

Semiotic competences are related to interpretation of data and symbols, which, in the case of endodontics, are related to communicating with patients and interpreting the data provided by them. These semiotic competences are intimately related to diagnostic skills and include, "among other things, the skill of

* Corresponding author.

[1] Pre-clinic courses are those that the student have to complete before his or her clinic internship

[2] Emphasis courses are optional courses that deal with advance topics on the different disciplines of dentistry. Students can select emphasis courses according to their personal o professional interests.

[3] There are 11 basic diagnosis in endodontics, which are covered in the first pre-clinic course. However, there are other conditions that could include endodiotic signs or diseases. For example, a periodontic condition could result in an endodontic disease. Those associated conditions are not covered in the first pre-clinic course nor in RealTeeth.

M., S., Gómez-Morantes, J., Parra, C., Carrillo-Ramos, A., Camacho, A. and Moreno, G.
Development of Diagnostic Skills in Dentistry Students using Gamified Virtual Patients.
DOI: 10.5220/0007708001240133
In *Proceedings of the 11th International Conference on Computer Supported Education (CSEDU 2019)*, pages 124-133
ISBN: 978-989-758-367-4

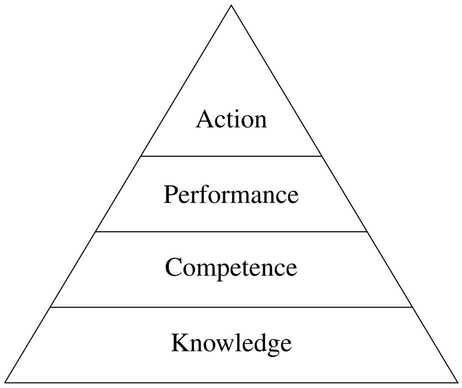

Figure 1: Miller's pyramid: Framework for clinical assessment. Adapted from (Miller, 1990).

acquiring information from a variety of human and laboratory sources, to analyze and interpret these data, and finally to translate such findings into a rational diagnostic or management plan" (Miller, 1990, p. S63).

Finally, the third course is an elective course with advanced semiotic and clinical competences for students with a special interest in endodontics.

Students start their clinic internship to put in practice and further develop the knowledge and skills acquired in the pre-clinic courses. Since this is where they put their skills into practice and get access to real patients, this is where performance and action assessment takes place (Miller, 1990).

This teaching structure, based on a pre-clinic component and a clinic internship, is commonplace in medical education (Miller, 1990; Brailovsky et al., 2001; Brailovsky, 2001). However, climbing Miller's pyramid is a considerable challenge. In the assessment front, there is a tendency to believe that knowledge should be the core of medical education assessment. As Miller says, "there are many who appear to believe that this *knowledge* base is all that needs to be measured" (Miller, 1990, p. S63, emphasis in original). This view could be attributed to the difficulties of assessments at the competence or performance levels without including real patients.

The training front faces similar challenges. Since the development of real-life skills is difficult from a classroom, most teaching efforts are geared towards the knowledge level of Miller's pyramid. However, since knowledge does not necessarily translate to skill, competence and skill building remains elusive. Some teaching methods like problem-based learning have been explored as a possible solution for this issue, but they have shown mixed results at the pre-clinic level (Hartling et al., 2010). More recently, and due to moderm technological advancements included in medical education, simulation elements have been introduced as a way to facilitate the competence building process and its assessment (Gaba, 2004; Issenberg et al., 2005).

It is clear, then, that new skill and competence building methods should be explored in pre-clinic endodontics education to avoid the shortfalls of a knowledge-centric medical education. With that in mind, this research proposes a simulation approach materialized in a serious game in which pre-clinic students have to act as dentists for virtual patients and reach an adequate diagnosis. The objective behind this technology introduction is twofold; first, there is the objective of providing a tool for students to exercise and develop their diagnostic skills. Second, it can be used to asses the knowledge and competence levels of Miller's pyramid.

This paper starts with a brief overview of the relevant literature in section 2. The methodology followed in this research is presented in section 3. Afterwards, section 4 presents more details about RealTeeth and the pilot validation performed during this research. Finally, the paper concludes in section 5 with a discussion about the lessons learned during this project and outlines a research agenda based on these lessons.

2 RELATED WORK

Computer supported education is a strong trend that has permeated more and more disciplines as time goes by. Endodontics, or dentistry at a more general level, is no stranger to this trend and there is already a strong body of work exploring the intersection between digital technologies and dentistry education. The current literature in this domain can be classified in three groups; the adoption of digital technologies among dentistry students, teachers, or schools; the use of digital technologies as an educational tool; and the education and training in digital technologies specific to the dentistry profession.

The literature on adoption of digital technologies among students, teachers, or schools follows a traditional adoption studies approach to evaluate acceptance, adoption factors, or likelihood of adoption of digital technologies among the aforementioned groups. In general, there seems to be an adequate set of adoption factors like previous experience with digital technologies (e.g. the Internet, smart phones, personal computers) by students and teaches (López Jordi et al., 2016; Mariño et al., 2012), and positive attitudes towards the use of digital technologies as a teaching aid (López Jordi et al., 2016; McCann et al., 2010; Ren et al., 2017; Amer et al., 2011). However, there are warnings against purely virtual models. In this sense, (McCann et al., 2010) indicates that most students see digital learning tools as complements to face-to-face teaching rather than a replacement. This is consistent with the work of (Reissmann et al., 2015) that demonstrates a high acceptance of blended models and the use of digital learning tools by dentistry students.

There are, however, few studies that focuses explicitly on the adoption rate of digital learning tools among dentistry schools. This is a big gap in the literature because, as (Ren et al., 2017) shows, acceptance and intention to adopt does not necessarily lead to actual adoption of digital technologies in the classroom.

The literature on the actual use of digital learning tools in dentistry education is more diverse, covering the development of virtual patients or serious gaming for dentistry students, the development of learning platforms (Bravo-Torres et al., 2017; MacPherson and Brueckner, 2003), and the evaluation of impact of digital learning tools in the performance of dentistry students.

Serious games for education, or game-based learning (GBL), is a popular subject in computer-supported education literature. At its core, serious games explores the use of game technologies or mechanics in education applications. In this sense, and because of the interactive nature of games, it lends itself to support problem-based, inquiry based or learning-by-doing methodologies (Shih et al., 2010). In terms of technologies, virtual reality, mobile or ubiquitous computing, digital social networks, and adaptive systems are among the most common technologies used in the development of GBL systems (Shih et al., 2010). Virtual reality and human-computer interaction technologies allow for the development of 3D systems that could be manipulated by traditional means (keyboard and mouse peripherals) or more sophisticated means like Nintendo Wii remotes, Microsoft Kinect sensors, or wired gloves. In this sense, virtual reality in GBL could lead to an immersive experience for students. Mobile an ubiquitous technologies could be used to support location-based learning (e.g. field works or explorations) and uses GPS information to create an augmented reality experience for students. Digital social networks can be used to implement social-heavy GBL systems or to integrate social features in other GBL tools. Finally, adaptive systems can be used in conjunction with other technologies to create GBL tools that adapt to different aspects of the use like preferences, learning pace, learning styles, among others.

The development of virtual patients, usually accompanied by gamification elements, is the most common for of game-based learning in the field of dentistry and is a popular theme in this literature (Antoniou et al., 2014; Sipiyaruk et al., 2017; Vannaprathip et al., 2016). However, as pointed out in (Sipiyaruk et al., 2017), serious games have some limitations and teachers should be cautious about the mix up of education and gaming objectives by students.

The impact of these digital learning tools on the performance of dentistry students has been studied with some detail, but no consensus has been reached in this regard. While some studies suggest a positive impact (Busanello et al., 2015; Ratka-Krüger et al., 2018), other found no statistically significant impact when comparing traditional teaching techniques with new computer-supported teaching techniques (Amer et al., 2011). Indirect measures of the effectiveness of digital learning tools can also be found in the literature. One example is the work of (Jackson et al., 2018) studying the usage patterns of self-directed digital learning tools and finding a strong tendency towards heavy usage in the days leading up to examinations. Given that the heavy lifting of preparation for examinations is usually left for 2 or 3 days before the exam, the fact that students invest such valuable time in digital learning tools is an indicator of their value.

This discrepancy could be explained, in part, by exploring the adequacy of digital learning tools in different education levels. In this sense, (Browne et al., 2004) found that face-to-face interaction was more effective for inexperienced learners (e.g. undergrad students), while e-learning was more effective for experienced learners (e.g. professional dentists enrolled in a continuous professional development program).

Finally, the literature on education and training in digital technologies specific to the dentistry profession explores the transition towards a professional practice with increasing number of digital components and tools (Afshari et al., 2017), and the challenges of training dentistry students in techniques such as CAD/CAM technologies, digital radiography, or digital microscopy (Afshari et al., 2017; Brownstein et al., 2015; Farah and Maybury, 2009).

The literature reviewed in this section demonstrates 3 main things; the adequacy of computer supported teaching methods in dentistry, the predominance of blended models over purely virtual models, and the challenges and risks of the implementation of digital learning tools in dentistry curricula. Of particular importance for this project, this literature shows the importance of keeping a balance between gamification and pedagogical elements in serious games, and the importance of truly integrating digital learning tools as complements to face-to-face teaching.

3 METHODOLOGY

The methodology followed in this research had three main phases; a learning styles diagnosis, a scenario design, and the development of the RealTeeth online game. Finally, a pilot validation with a cohort of pre-clinic students was performed.

In order to determine the best kind of content to include in the simulations, a learning styles diagnosis among pre-clinic endodontics students was performed based on the visual, auditory, and kinaesthetic (VAK) learning styles (Bandler and Grinder, 1990). A questionnaire with 40 closed-answer questions[4] was distributed in a cohort of pre-clinic endodontics students, obtaining 32 fully answered questionnaires. The results of these questionnaires indicated that most students were predominantly kinaesthetic (42%) or visual (39%) learners, while only 19% were predominantly auditory learners.

The main objective of this assessment was to prioritize the time and resources devoted to the different kinds of materials that could be included in this type of simulations. With that in mind, and considering that only 19% of students are predominantly auditory learners, no auditory elements will be included in the simulation. Visual learners, on the other hand, represent 39% of students. Hence, the simulation will be rich in visual aids like x-rays and photos from real cases to guide the user experience. Kinaesthetic learners are a challenge because kinaesthetic learning implies movement and usage of tools. However, since this project is focused on semiological competences, which have little intersection with movement in the case of endodontics, no real kinaesthetic elements will be included in the simulation.

The scenario design phase focused on the design of user experience and the learning experience for the students. This included a case model, an evaluation model, and a gamification context design. This was done in conjunction with the current teachers of the pre-clinic endodontics courses. These designs were later used for the development of RealTeeth, which was done following a Scrum software development lifecycle to allow for constant validation and feedback from the endodontics teaching team. For a pilot validation, RealTeeth was then deployed and tested with a cohort of 19 dentistry students and 3 domain expert (see Figure 2).

Since this paper reports only on the initial development of RealTeeth, the results from the pilot validation phase are commented in section 4.3, but haven't been included nor implemented at the time of writing.

[4]The questionnaire was taken from (De la Parra Paz, 2004, p. 85)

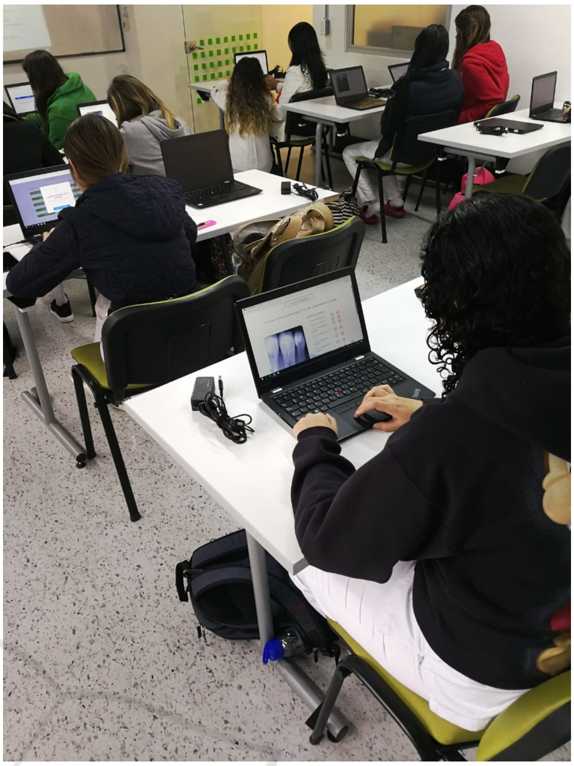

Figure 2: Pilot test of RealTeeth.

4 REALTEETH

RealTeeth could be described as a patient simulator that was designed and developed as an answer to the challenges for endodontics education in the Pontificia Universidad Javeriana (see section 1). It covers the two pre-clinic courses and the elective course; and contributes to the knowledge, competence, and performance levels of Miller's pyramid. Furthermore, it includes gamification elements to facilitate and stimulate usage and learning from endodontics students. To facilitate it's deployment and usage, it is built as a web application.

RealTeeth puts the student in the place of a newly graduated dentist looking for a job position at a big dentistry practice. In order to get the job, the student has to show his or her endodontics skills by diagnosing 10 patients (see Figure 3). Once the 10 virtual patients are diagnosed, the student will be classified in a basic-intermediate-advanced scale. Students with an advanced classification will be offered the position of Chief Endodontist. Students with an intermediate classification will be offered the position of Junior Endodontist. Finally, students with a basic classification will see their job application rejected.

Every student starts at a basic level and will be

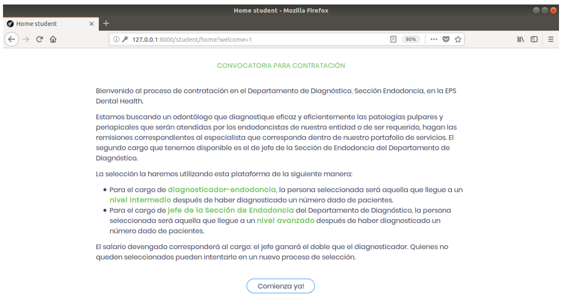

Figure 3: RealTeeth welcome screen for students.

presented with basic-level cases until he or she advances to the intermediate level. In order to do this, the student has to get three consecutive basic-level cases right. Once this happens, the student will be presented with intermediate-level cases. If the student is capable of getting three consecutive intermediate-level cases right, he or she will move to the advanced level and will be presented with advanced-level cases (see Figure 4). The student will be demoted to the previous level if he or she fails a case.

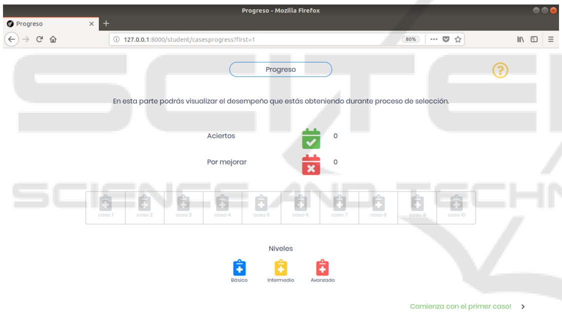

Figure 4: RealTeeth dashboard screen for students.

The cases are structured around the standard diagnosis protocol in endodontics (see Figure 5). Cases have 5 possible diagnostic routes; pain assessment, clinical exam, periapical tests, sensibility tests, and x-rays. The student can choose any of the 5 diagnostic routes to start his diagnosis. Each diagnostic route will give different information, and some of them (e.g. x-rays or clinical exam) will show images or photos (see Figure 6). Additionally, each diagnostic routes allow the student to ask questions and RealTeeth will provide answers[5]. At the end of a diagnostic route the student has to reach a conclusion based only on the information provided by the route (see Figure 7). After completing the 5 diagnostic routes the student can finally provide a diagnosis (see Figure 8). Based on the conclusions of the 5 diagnostic routes and the final diagnosis, the case is evaluated using a rubric and provides feedback to the student (see Figure 9).

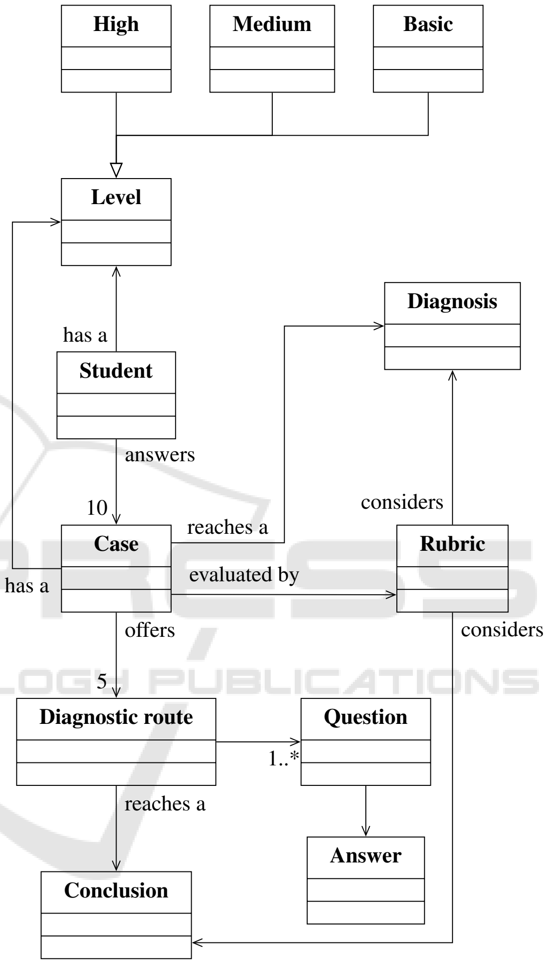

Figure 5: Case model.

The use protocol is as follows (see Figure 10). The student starts by seeing an introductory screen explaining the rules of the game. The student then starts with the first case in basic level. A case introduction is shown at the beginning of each case with information regarding the reason for consultation given by the patient. Later, the student can choose one of the five diagnostic routes and follow it until a conclusion is reached on that route. When the student completes the 5 routes, a diagnosis must be given. The case will be evaluated using a pre-defined rubric and the student will be informed if the case was passed or not. Based on previous performance, the student will be

[5]The nature of the questions and answers depends on the nature of the diagnostic route. The clinical exam, for example allows the student to ask additional questions to the patient and RealTeeth will show the answer given by the patient. X-rays, on the other hand, allow the student to ask questions about the x-ray and RealTeeth will provide expert answers.

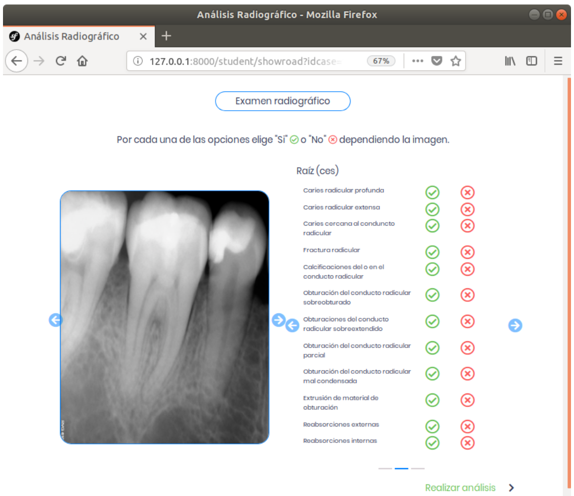

Figure 6: Main screen of the x-ray examination diagnostic route.

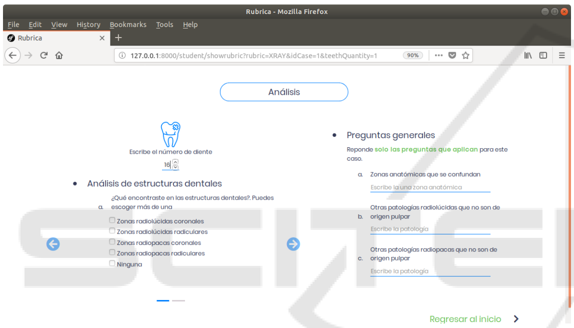

Figure 7: Analysis screen of the x-ray examination diagnostic route.

promoted or demoted. This process will be repeated until the student completes 10 cases. Once this happens, the result of the game session will be shown to the student.

The interaction between the student and RealTeeth throughout this process is form-based and gives a great deal of control to the student. In this sense, the student can choose where to start (i.e. the order of the diagnostic routes) and the order in which to ask questions to the system. The student can also go back to previous diagnostic routes to double check information or change his or her diagnostic. After the final diagnosis is made, the student is shown if this diagnosis is correct or not. Additionally, the details of the evaluation (i.e. the full rubrics for every diagnostic route) is shown (see figure 9) in order to allow the student to analyze his or her performance and identify any weaknesses that should be addressed.

4.1 Case Design and Teacher-oriented Features

This initial version of RealTeeth offers 4 features for teachers: case creation, case editing, case search, and case removal.

The case creation feature allows teachers to create a complete case, including case description, basic information for the 5 diagnostic routes, uploading of x-rays and other images used in the case, the questions and answers of each diagnostic route, the conclusions for each diagnostic route, the right diagnosis for the case, and the evaluation rubric.

The case editing feature allows teachers to modify the information and structure of a pre-defined case. This was proven to be of key importance during our pilot validation of RealTeeth since even though the cases were designed by experts on the field, some minor errors where discovered in the cases. These errors where detected when too many students were failing the same case, when students capable of reaching an advanced level were consistently failing the same lower-level case, or when differences of opinion about a case level arouse among the teaching team.

The case search feature allow teachers to find cases based on the difficulty level.

Finally, the case removal feature allow teachers to delete one or multiple cases.

4.2 System Architecture

RealTeeth was developed using a traditional web-oriented architecture following the Model-View-Controler (MVC) pattern. The backend was developed in PHP using the Symfony 2.7 framework. The frontend was developed using Javascript, HTML 5 and CSS 3. Finally, MySQL was used as DBMS. The system was deployed using Amazon Web Services. Specifically, AWS EC2 was used to host RealTeeth, and AWS RDS was used to handle the database (see Figure 11). It is important to note, however, that RealTeeth can be deployed in any linux-based server with Apache Web Server, PHP, and MySQL installed.

4.3 Pilot Validation

Two kinds of tests were done in RealTeeth: functional testing and usability testing.

The functional testing was done using the PHPUnit testing framework and following the Clean Code (Martin, 2009) and SOLID principles (Arora, 2017). Additionally, RealTeeth has been tested in the latest versions (at the time of writing) of Google Chrome, Mozilla Firefox, and Safari web browsers.

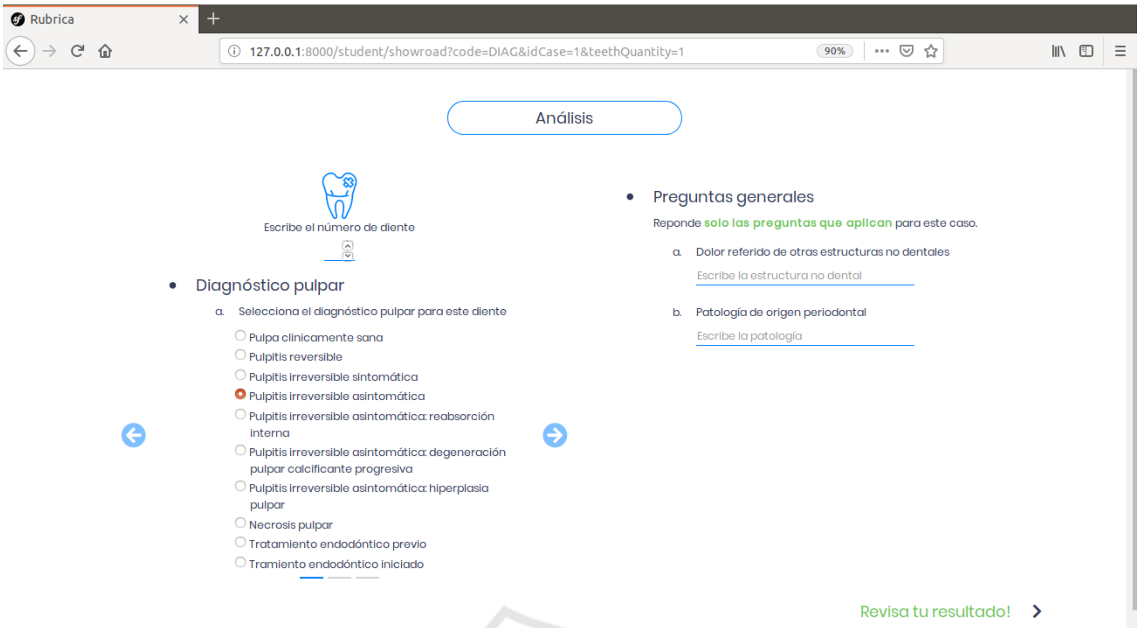

Figure 8: Case diagnosis screen.

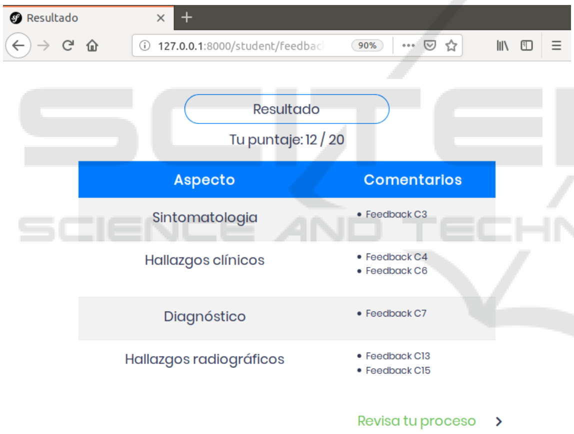

Figure 9: Results and feedback screen.

The usability test was done using a survey handed to the 19 students that participated in the pilot test of RealTeeth. This usability test evaluates the effectiveness, efficiency, and user satisfaction of RealTeeth following the ISO 9241-11 and ISO/IEC 9126-4 standards. The main results from this usability test are that the gamification elements included in RealTeeth were well understood and accepted by the students. However, a general comment was that these gamification elements should be further developed to increase the motivation of the student. Some ideas gathered in the questionnaire included stating different salaries for the different job positions offered at the beginning of the game, or including different perks associated with each job position. This highlights the importance of gamification to ensure user engagement in digital learning tools.

Regardless of some user interface problems (e.g. button placement, text size and fonts, confusing navigation at especific points, etc.), the pilot validation could be considered a success. Furthermore, and regardless of these navigation issues, the students seem very satisfied with RealTeeth, with 100% stating that the information provided in RealTeeth was close to real-life cases and 81% stating that they would like to use RealTeeth frequently. Finally, some of the comments made by the students include "*this is something new in pre-clinic and would be interesting to use it during the semester*", "*this was an interesting exercise and we've never done anything like this before*", and "*this helps to close the gap between theory and practice*". This shows that RealTeeth was capable of fulfilling the objective highlighted in section 1.

5 LESSONS LEARNED AND FUTURE WORK

The pilot validation of RealTeeth suggests that it has high acceptance levels from both students and faculty. Additionally, there seems to be a high perception of usefulness coming from students and faculty. But regardless of this positive attitude towards RealTeeth, or digital learning tools in general, this experience yielded valuable lessons for future versions of RealTeeth.

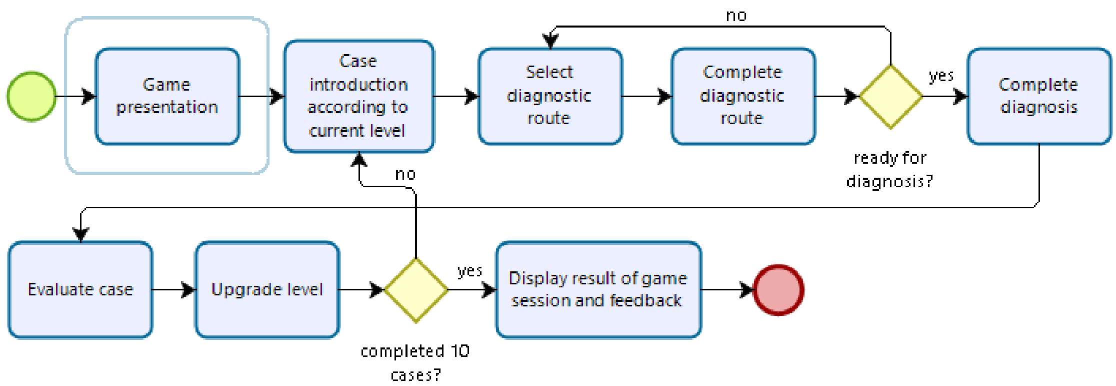

Figure 10: RealTeeth use protocol.

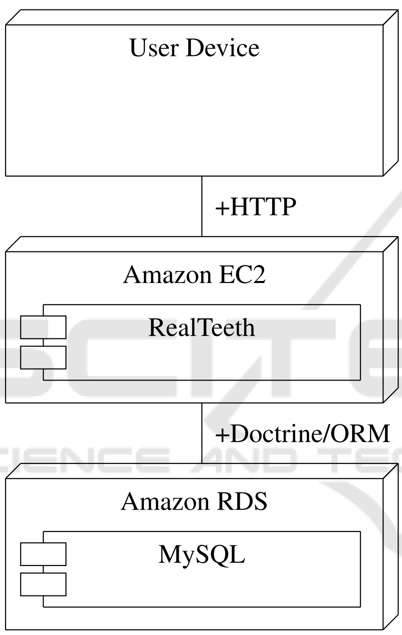

Figure 11: Deployment diagram for the RealTeeth system.

The first lesson is that digital learning tools should be designed for classrooms and not for individual students. This was evident in the case creation-process, especially when it came to assigning a difficulty level to the cases. The current version of RealTeeth relies on expert opinion (i.e. faculty member) as the only input to assign the difficulty level to cases. However, since case difficulty is subjective, some difference of opinion did arise during this process. Having more input sources, such as the historical performance of a good amount of users, will allow for a more objective and dynamic assignment of difficulty levels. In this sense, future versions of RealTeeth should be able to consider the performance of several students in each case to provide information usable for, for example, assigning the difficulty level of cases in a dynamic and objective manner, flagging cases with incomplete or inconsistent information (e.g. cases in which even high-performing students fail consistently), and discovering topics that should be revisited in class or in external tutoring sessions (e.g. topics that are heavily present in cases in which a particular set of students are showing an atypical failure rate).

Additionally, this would allow for the inclusion of further gamification elements like students leagues or leaderboards.

A second lesson was the importance of deep personalization of the user experience according to previous performance. In its current version, RealTeeth only uses the difficulty of previous failed/passed cases in order to select the next case for the student. However, since diagnosis skills are multidimensional, faculty member expressed their desire for cases to be selected not only based on difficulty level but also on diagnosis dimension. In this sense, a student with problems in one diagnosis dimension will be shown cases that focus on that particular dimension (i.e. cases in which the most important information is in the x-ray evaluation or cases in which the most important information is in the periapical test). The student can also be given the option to select a diagnosis dimension to use in a particular RealTeeth session. This will allow students to identify and work on their weaknesses or to focus their preparation for specific examinations.

Beyond these lessons, this experience, coupled with the literature review shown in section 2, can be used to inform the research agenda on computer supported education in the field of dentistry.

The first and perhaps more important area of further research is the impact of digital learning tools in dentistry education and the factors that determine this impact. As shown in section 2, there is no consensus on the impact of digital technologies on the performance of dentistry students or professionals. Additionally, there seems to be external factors (i.e. factors that are not within the boundaries of the digital learning tool) that determine the impact of these tools on the performance of students (Browne et al., 2004). More research on this area is imperative not only to determine if digital learning tools do indeed have a positive impact on student's performance (hence making them worthy of attention by researchers on the field and dentistry schools) but also under what conditions (hence triggering changes in course design, instructional design, curricula, or classroom material).

The second area of further research is inspired by (Bravo-Torres et al., 2017), and (Jackson et al., 2018) and has to do with the adoption and usage pattern of digital learning tools by students, faculty, and schools. Key questions on this regard include what are the adoption factors of digital learning tools in the field of dentistry?, what is the pattern followed by this adoption?, what usage is given to digital learning tools by dentistry students and faculty members?, and what is the relationship between digital learning tools and traditional training in the filed of dentistry?. Additionally, for the case of serious games, and following the findings of (Sipiyaruk et al., 2017), it is important to do more research on the prevalence of learning objectives over gaming objectives of serious games.

Finally, it is important to note that most research on the field is centred on students and there is little work centred on faculty members or schools. More research tackling the role, challenges, and impacts of this set of actors in computer supported education in the field of dentistry is much needed.

REFERENCES

Afshari, F., Sukotjo, C., Alfaro, M., McCombs, J., Campbell, S., Knoernschild, K., and Yuan, J.-C. (2017). Integration of digital dentistry into a predoctoral implant program: Program description, rationale, and utilization trends. *Journal of Dental Education*, 81(8):986–994.

Amer, R., Denehy, G., Cobb, D., Dawson, D., Cunningham-Ford, M., and Bergeron, C. (2011). Development and evaluation of an interactive dental video game to teach dentin bonding. *Journal of Dental Education*, 75(6):823–831.

Antoniou, P., Athanasopoulou, C., Dafli, E., and Bamidis, P. (2014). Exploring design requirements for repurposing dental virtual patients from the web to second life: A focus group study. *Journal of Medical Internet Research*, 16(6).

Arora, G. K. (2017). *SOLID Principles Succinctly*. CreateSpace Independent Publishing Platform.

Bandler, R. and Grinder, J. (1990). *Frogs Into Princes: The Introduction to Neuro-Linguistic Programming*. Eden Grove Editions.

Brailovsky, C., Charlin, B., Beausoleil, S., Coté, S., and Van der Vleuten, C. (2001). Measurement of clinical reflective capacity early in training as a predictor of clinical reasoning performance at the end of residency: an experimental study on the script concordance test. *Medical education*, 35:430–436.

Brailovsky, C. A. (2001). *Educación médica, evaluación de las competencias*, pages 103–122.

Bravo-Torres, W., Alvarado-Cordero, J., Cevallos-Ludeña, C., Vintimilla-Tapia, P., Bravo-Torres, J., and Gallegos-Segovia, P. (2017). DentaLAV: A virtual platform for dental multidisciplinary learning. In *2017 IEEE Colombian Conference on Communications and Computing, COLCOM 2017 - Proceedings*.

Browne, L., Mehra, S., Rattan, R., and Thomas, G. (2004). Comparing lecture and e-learning as pedagogies for new and experienced professionals in dentistry. *British Dental Journal*, 197(2):95–97.

Brownstein, S., Murad, A., and Hunt, R. (2015). Implementation of new technologies in U.S. dental school curricula. *Journal of Dental Education*, 79(3):259–264.

Busanello, F., da Silveira, P., Liedke, G., Arús, N., Vizzotto, M., Silveira, H., and Silveira, H. (2015). Evaluation of a digital learning object ({DLO) to support the learning process in radiographic dental diagnosis. *European Journal of Dental Education*, 19(4):222–228.

De la Parra Paz, E. (2004). *Herencia De Vida Para Tus Hijos: Crecimiento Integral con Tecnicas PNL*. Ed. Grijalbo.

Farah, C. and Maybury, T. (2009). Implementing digital technology to enhance student learning of pathology. *European Journal of Dental Education*, 13(3):172–178.

Gaba, D. M. (2004). The future vision of simulation in health care. *Quality and Safety in Health Care*, 13(suppl_1):i2–i10.

Hartling, L., Spooner, C., Tjosvold, L., and Oswald, A. (2010). Problem-based learning in pre-clinical medical education: 22 years of outcome research. *Medical Teacher*, 32(1):28–35.

Issenberg, S. B., Mcgaghie, W. C., Petrusa, E. R., Gordon, D. L., and Scalese, R. J. (2005). Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Medical Teacher*, 27(1):10–28.

Jackson, T., Zhong, J., Phillips, C., and Koroluk, L. (2018). Self-directed digital learning: When do dental students study? *Journal of Dental Education*, 82(4):373–378.

López Jordi, M., Figueiredo, M., Barone, D., and Pereira, C. (2016). Study and analysis of information technology in dentistry in Latin American countries. *Acta odontologica latinoamericana : AOL*, 29(1):14–22.

MacPherson, B. and Brueckner, J. (2003). Enhancing the dental histology curriculum using computer technology. *Journal of dental education*, 67(3):359–365.

Mariño, R., Habibi, E., Morgan, M., and Au-Yeung, W. (2012). Information and communication technology use among Victorian and South Australian oral health professions students. *Journal of Dental Education*, 76(12):1667–1674.

Martin, R. C. (2009). *Clean Code: A Handbook of Agile Software Craftsmanship*. Prentice Hall.

McCann, A., Schneiderman, E., and Hinton, R. (2010). E-teaching and learning preferences of dental and dental hygiene students. *Journal of Dental Education*, 74(1):65–78.

Miller, G. E. (1990). The assessment of clinical skills/competence/performance. *Academic medicine*, 65(9):S63–67.

Ratka-Krüger, P., Wölber, J., Blank, J., Holst, K., Hörmeyer, I., and Vögele, E. (2018). MasterOnline Periodontology and Implant Therapy—revisited after seven years: A case study of the structures and outcomes in a blended learning CPD. *European Journal of Dental Education*, 22(1):e7–e13.

Reissmann, D., Sierwald, I., Berger, F., and Heydecke, G. (2015). A model of blended learning in a preclinical course in prosthetic dentistry. *Journal of Dental Education*, 79(2):157–165.

Ren, Q., Wang, Y., Zheng, Q., Ye, L., Zhou, X., and Zhang, L. (2017). Survey of student attitudes towards digital simulation technologies at a dental school in China. *European Journal of Dental Education*, 21(3):180–186.

Schwaber, K. (2004). *Agile project management with Scrum.* Microsoft Press, Redmond, WA, USA.

Shih, T. K., Squire, K., and Lau, R. W. H. (2010). Guest Editorial: Special Section on Game-Based Learning. *IEEE Transactions on Learning Technologies*, 3(4):278–280.

Sipiyaruk, K., Gallagher, J., Hatzipanagos, S., and Reynolds, P. (2017). Acquiring Critical Thinking and Decision-Making Skills: An Evaluation of a Serious Game Used by Undergraduate Dental Students in Dental Public Health. *Technology, Knowledge and Learning*, 22(2):209–218.

Vannaprathip, N., Haddawy, P., Suebnukarn, S., Sangsartra, P., Sasikhant, N., and Sangutai, S. (2016). Desitra: A simulator for teaching situated decision making in dental surgery. In *International Conference on Intelligent User Interfaces, Proceedings IUI*, volume 07-10-March-2016, pages 397–401.