JHANDIRA DAIBELIS YAMPA VARGAS

Active teaching-learning approaches for teaching caries detection to undergraduate students – findings from a pragmatic multicentre trial

São Paulo

2023

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Corrected Version

Thesis presented to the School of Dentistry of the University of São Paulo, by the Graduate Program in Dental Sciences to obtain the degree of PhD in Sciences.

Concentration Area: Pediatric Dentistry and Orthodontics

Supervisor: Dr. Mariana Minatel Braga

São Paulo

2023

Catalogação da Publicação
Serviço de Documentação Odontológica
Faculdade de Odontologia da Universidade de São Paulo

Yampa Vargas, Jhandira Daibelis.
Active teaching-learning approaches for teaching caries detection to undergraduate students – findings from a pragmatic multicentre trial / Jhandira Daibelis Yampa Vargas; supervisor Mariana Minatel Braga -- São Paulo, 2023.
200 p. : fig., tab. ; 30 cm.

Thesis (Doctorate degree) -- Graduate Program in Dental Sciences. Concentration Area: Pediatric Dentistry and Orthodontics -- Faculty of Dentistry, University of São Paulo.
Corrected version.

1. Multicenter Studies as Topic. 2. Education. 3. Dental. 4. Active Learning.5. Dental Caries. I. Braga, Mariana Minatel. II. Title.

Glauci Elaine Damasio Fidelis – Librarian - CRB8/6959

Yampa-Vargas JD. Active teaching-learning approaches for teaching caries detection to undergraduate students – findings from a pragmatic multicentre trial [Thesis] presented to the Dental School, University of São Paulo to obtain the degree of PhD of Sciences.

Approved in: __25__/_05__/__2023__

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Dedico este trabajo a mi querida familia, en Bolivia:

Pascual, Juana, Paola y Pablo

¡Con todo cariño para ustedes! que me ayudaron a construir este logro, soñaron conmigo cada etapa y me incentivaron para poder llegar hasta aquí!
¡gracias por todo!

ACKNOWLEDGEMENTS / AGRADECIMIENTOS

I would like to express my sincere gratitude towards all those who have supported me throughout my thesis work, especially my supervisors Dr. Braga and Dr. Lara for their guidance, encouragement, and valuable feedback throughout this process.

I am deeply grateful, as well, to the members of the defense thesis board: Dr. Angeles Martinez, Dr. Fernanda Carrer and Dr. Kim Ekstrand, for your valuable contribution and for the time and effort dedicated to this work. Your guidance and feedback will be crucial for improving the quality of this research.

I wish to also express my profound gratitude to all the esteemed members of the IUSTC collaborative research group, as well as, all the institutions (dental schools) that were involved in this research. Thank you for the invaluable assistance and support throughout the different stages of this work. Today It is with great honor and privilege that I represent them.

I also extend my gratitude toward my research colleagues and the whole staff of the University of São Paulo and the Indiana University school of Dentistry for their support during my research.

. . .

Going forward, please allow me to express my sincerest apologies in advance, because I'm going to switch between languages in the following paragraphs. I am blessed to have such wonderful people in my life and I would like to take this opportunity to express my appreciation to those that had a significant role in this journey. So, get ready for some Portunhol or Spanglish maybe...

. . .

No podria continuar sin decir que agradezco, en primer lugar, a DIOS y a la Virgencita de Guadalupe por su infinita protección. Por estar conmigo a todo momento y cuidar de cada uno de mis pasos. A todos mis angelitos que me cuidan desde el cielo ¡muchas gracias!

A mi querida familia, en Bolivia, ¡mil gracias! A todos los "Yampa", y a todos los "Vargas" porque cada vez que los visito, ¡me reciben con tanto cariño y

continúan incentivándome a seguir adelante! ¡Gracias a todos! porque la distancia me enseñó a valorizar cada vez más su cariño.

A mis papás... **Juana y Pascual** ¡Gracias por ser mi incentivo diario! Por su amor y apoyo incondicional durante todo este tiempo y principalmente por toda su dedicación y sacrificios realizados para que yo pudiera llegar hasta aquí.

A mis herman*itos*, **Paola y Pablo,** que ya no son tan chiquititos, pero que siempre serán mi orgullo. Los quiero mucho y sepan que siempre estaré aquí para apoyar todos sus sueños y objetivos.

À minhas famílias brasileiras...muito obrigada por me adotar! Deus é tão bom que quando saí de casa e pensei que iria estar sozinha, ele me presenteou com vários lares para chamar de meus!

Neuza, Tori, Mayko e Vitória, obrigada por me receber desde o primeiro dia, se não fosse esse apoio e acolhida talvez hoje nem estaria aqui. Vocês abriram, não só a porta da sua casa, más também a dos seus corações. Obrigada por todo o cuidado e carinho comigo e por me fazer sentir parte da família.

Maria Paula, Augusto e Michelli, obrigada pelo carinho e preocupação comigo... vocês me colocaram dentro do seu lar e me fizeram virar mais uma integrante da família... obrigada por todos os conselhos, o apoio e incentivo.

Aos filhos **da dona Maria,** e a todos seus agregados! Que família hein! Muito obrigada por me receber de uma forma tão amiga e generosa, vocês me acolheram e acompanharam durante todo esse tempo e tenho um enorme carinho por cada um de vocês. Obrigada especialmente ao **Dodô,** o mais prestativo de todos!! Kkk, obrigada por entrar na minha vida e me tornar uma pessoa melhor! Você realmente pegou da minha mão e me mostrou os caminhos!! Me ajudou e acompanhou desde o início, dando permanente incentivo. Saiba que sou muito grata por isso!

...

De maneira muito especial quero agradecer:

À Universidade de São Paulo e ao Programa de pós-graduação em Ciências Odontológicas da Faculdade de Odontologia, por ser uma instituição acolhedora, que me abrigou e se tornou uma segunda casa para mim nestes 8 anos de estudos, entre a realização de estágios, mestrado e doutorado. Obrigada a todos

os funcionários que trabalham da melhor maneira para formar profissionais de excelência e para que a instituição seja reconhecida mundialmente. Aqui tive oportunidade de me desenvolver como profissional e pude trabalhar com pessoas muito competentes e queridas. Certamente ter estudado aqui me enche de orgulho!!!

<u>À minha querida Orientadora Mari</u>

Obrigada, minha "mãe científica", minha guia e minha luz neste processo tão desafiador. Mari sem você nada de isto seria possível! Obrigado por ter me acompanhado durante todo esse caminho e principalmente obrigada por me receber de braços abertos quando cheguei da Bolívia. Você, mesmo sem me conhecer, me deu sua confiança e abriu as portas para mim, foi me incentivando, ensinando e ajudando constantemente para que chegasse até aqui. Mari, agradeço por cada minuto da sua atenção e dedicação, foi uma honra tê-la como orientadora, aprendi muito ao seu lado e hoje levo comigo uma bagagem muito linda.

À os demais membros da Banca Examinadora, **<u>Profa. Karla Rezende, Profa. Tathiane Lenzi e Prof. Imparato,</u>** meu profundo agradecimento pela disponibilidade para participar da Defesa, pelo tempo dedicado à leitura da tese e principalmente por todo o carinho comigo.

À **CAPES** (Coordenação de Aperfeiçoamento de pessoal de nível superior) pela concessão da Bolsa durante o curso. E durante o Programa de internacionalização **PrInt USP-Capes,** que me concedeu a magnífica oportunidade de realizar o Doutorado Sanduíche no Exterior, na universidade de Indiana, nos Estados Unidos.

Ao meu querido orientador internacional Dr. Juan Sebastian Lara, a quien admiro profundamente por toda su trayetória y le agradezco inmensamnete por todas las oportunidades brindadas. Hago extenso mi agradecimento también a todos los docentes y funcionarios de la universidad extranjera que me recibieron con mucho cariño

Agradeço também a todos os **professores do Departamento de Odontopediatria da FOUSP: Profa. Daniela Raggio, Prof. Fausto Mendes, Prof. Marcelo Bönecker,**

Profa. Marcia Wanderley, Prof. Ana Estela Haddad, Profa. Ana Lídia, e Prof. Salete, grandes mestres que sempre transmitem seu saber com muito profissionalismo. Tenho muita admiração e respeito por cada um de vocês.

Obrigada a todos os funcionários do departamento de Odontopediatria, especialmente a **Julinho (o mais lindo do mundo!), Annezinha Antônio e Fafá**, por serem tão prestativos, e fazer tudo o que está ao seu alcance para nos ajudar. Agradeço de todo coração!

Aos funcionários da **Pós-graduação: Cátia e Fernando,** que sempre estiveram dispostos a orientar e responder todas minhas dúvidas com toda a gentileza e simpatia.

Às funcionárias **de Biblioteca/SDO e gráfica,** especialmente **Glauci,** que é um anjinho na terra. Faz tudo que está ao seu alcance para ajudar a todos, e com toda sua paciência, empatia e cuidado acalma os corações daqueles que chegam até ela.

A toda equipe de pesquisa (maravilhosa) que trabalhou comigo (Marianetes e marianetos, rsrsr), muito obrigada a cada um de vocês por toda a parceria e amizade. Tive a oportunidade de conhecer e trabalhar com várias gerações de alunos e cada pessoa me deixou uma marquinha importante no coração. Às mais antigas: Karina, Betinha, Duda, Fe Roche, Raissa, Caroline, Fabi, Ana e Gabi, obrigada por tantas experiências divididas e pela parceria no dia a dia. Agradeço especialmente às alunas ***Gabriele de Oliveira e Thais Machado*** que estiveram sempre dispostas a ajudar durante a realização da pesquisa e participaram diretamente para a concretização deste trabalho.

Obrigada a todos os (as) colegas de pós-graduação, pela amizade e por todas as experiências junt@s, pelos momentos de descontração e alegrias. Desejo muito sucesso a cada um de vocês

A toda a equipe do **Trailer, Cardec e Clínica de Adolescentes** por me permitir trabalhar e aprender tanto com vocês

A todos! Que de alguma forma, direta ou indireta, me ajudaram a acreditar em mim para chegar até aqui, e converter em realidade o que começou como um sonho...**MUCHAS GRACIAS!!!!!**

"O que torna um sonho irrealizável, não é o sonho em si; se não, a inércia de quem sonha"–

Desconhecido.

"O que não te desafia, não te transforma"–

Desconhecido.

ABSTRACT

Yampa-Vargas JD Active teaching-learning approaches for teaching caries detection to undergraduate students – findings from a pragmatic multicentre trial. [Thesis]. São Paulo: University of São Paulo, Dental School; 2023. Corrected Version.

Although traditional lectures have been the most used strategies to teach Cariology, they may not be enough to develop expected dental students' competencies for caries detection. This thesis describes the results of a multicenter pioneer study in dental education from the collaborative research group @IuSTCariology (Initiatives for undergraduate Students' Training in Cariology) that proposed an alternative educational strategy for the students' training on caries detection. Its general aim was present results in terms of effectiveness and feasibility of implementation in the real world (practicality, expansion, adaptation) and economic impact. The new strategy combines conventional learning methods, as the lecture, with "more active" educational resources. It includes preclinical tutored theoretical-practical training using images and extracted teeth as the basis for discussion and knowledge sedimentation. This methodology was tested in a multicentre randomized controlled trial (IuSTC study01). This study involved eleven dental schools worldwide. Undergraduate dental students were recruited from different universities and allocated into two groups, depending on the teaching method. Control group: only lecture (passive learning) and test group: lecture + training (active learning). More than a thousand undergraduate students were included in the trial. Particularities, challenges and solutions related to such implementation were included in Chapter 1. The impact of the teaching method on students' practical skills evaluated in the mentioned clinical trial is described in Chapter 2. Other learning and student-centred secondary outcomes were also explored in this chapter. Chapters 3 and 4 bring economic evaluations related to the implementation of the educational strategy. Chapter 4 also included a full economic evaluation to verify how efficiently resources could be allocated when implementing the new strategy in the dental education context. The challenges and difficulties that institutions faced in implementing the innovative pedagogical strategy during the recent COVID-19 pandemic are reported in Chapter 5.In summary, difficulties with students' motivation, overall planning and infrastructure were the main challenges during implementation. However, interesting solutions were created to overcome them and motivate the implementation partners to continue and disseminate its delivery. The theoretical-practical training positively impacted the students' practical skills for caries detection and improved the student-centred outcomes related to their performance. Besides, this active-learning training has been proven to be a cost-effective alternative to improve the students' practical skills in caries detection in substitution of traditional lectures, being a worthy investment to be disseminated in educational institutions. However, the incremental cost per student of the proposed educational activity implementation is relatively low and represents an investment in human resources; an organizational budget impact should be expected and planned. Finally, even with the challenges imposed by the pandemic, the activity seems adaptable in different formats and financially viable. In conclusion, the tutored theoretical-practical training improves dental students' practical ability to detect caries lesions. It is also feasible, adaptable and cost-effective option to implement from the educational decision-makers' perspective.

Keywords: Teaching Methods; Active Learning; Educational Measurement; Dental Caries; Cost-Benefit Analysis.

RESUMO

Yampa-Vargas JD. Metodologias ativas para o ensino de detecção de lesões de cárie na graduação em Odontologia - resultados de um estudo multicêntrico pragmático [dissertação]. São Paulo: Universidade de São Paulo, Faculdade de Odontologia; 2023. Versão Corrigida.

Embora aulas tradicionais tenham sido as estratégias mais utilizadas para ensinar Cariologia, elas podem não ser suficientes para desenvolver competências adequadas dos graduandos para detecção de lesões de cárie. Neste trabalho se descreve os resultados de um estudo multicêntrico do grupo de pesquisa colaborativa @IuSTCariology que propôs um estudo controlado e randomizado para avaliar diferentes estratégias educacionais como alternativa para o treinamento de alunos sobre detecção de lesões de cárie. Seu objetivo geral foi apresentar resultados em termos de eficácia e viabilidade de implementação no mundo real (praticidade, expansão, adaptação), além do impacto econômico. A nova estratégia que usa metodologias ativas, inclui um treinamento teórico-prático e laboratorial, guiado por tutores que utiliza imagens e dentes extraídos como base para discussão e sedimentação do conhecimento. Esta metodologia foi testada no estudo controlado randomizado e multicêntrico (IuSTC study01). Este estudo envolveu 11 faculdades de odontologia em diferentes países. Alunos de graduação em odontologia foram recrutados e alocados em dois grupos, dependendo do método de ensino que receberam. Grupo controle: recebeu aula teórica (aprendizagem passiva) e grupo teste: aula + treinamento tipo hands-on (aprendizagem ativa). Mais de mil alunos de graduação foram incluídos no estudo. Particularidades, desafios e soluções relacionadas a essa implementação foram descritos no Capítulo 1. O impacto do método de ensino sobre a aquisição ou melhora das habilidades práticas dos alunos avaliados no referido ensaio clínico é descrito no Capítulo 2. Outros resultados secundários de aprendizagem e centrados no aluno também foram explorados no este capítulo. Os capítulos 3 e 4 trazem avaliações econômicas relacionadas à implementação da estratégia educacional. O Capítulo 4 também incluiu uma avaliação econômica completa para verificar com que eficiência os recursos poderiam ser alocados ao implementar a nova estratégia no contexto da educação odontológica.

Os desafios e dificuldades que as instituições enfrentam na implementação da estratégia pedagógica inovadora durante a recente pandemia de COVID-19 são relatados no Capítulo 5. Em resumo, as dificuldades com a motivação dos alunos, planejamento geral e infraestrutura foram os principais desafios durante a implementação. No entanto, soluções interessantes foram criadas para superá-los e motivar os parceiros de implementação a continuar e disseminar sua entrega. O treinamento teórico-prático impactou positivamente nas habilidades práticas dos alunos para detecção de cárie e melhorou os resultados centrados no aluno relacionados ao seu desempenho. Além disso, este treinamento de aprendizagem ativa tem se mostrado uma alternativa custo-efetiva para melhorar as habilidades práticas dos alunos na detecção de cárie em substituição às aulas tradicionais, sendo um investimento valioso a ser disseminado em instituições de ensino. Embora, o custo incremental por aluno da implementação da atividade educacional proposta é relativamente baixo, ele representa um investimento em recursos humanos; um impacto no orçamento organizacional da instituição de ensino e deve ser esperado e planejado. Por fim, mesmo com os desafios impostos pela pandemia, a atividade parece adaptável em diferentes formatos e viável financeiramente. Em conclusão, o treinamento teórico-prático monitorado melhora a capacidade prática dos alunos de odontologia para detectar lesões de cárie. Também é uma opção viável, adaptável e econômica para implementar a partir da perspectiva dos tomadores de decisão educacional.

Palavras-chave: Ensino; Aprendizagem Baseado em Problemas; Carie Dentária; Avaliação de Custo-Efetividade.

CONTENTS

1 INTRODUCTION

The evolution and quality assurance of dental education are very relevant matters. Students who will graduate as dentists will later take care of real patients, and their training will be directly related to the quality of care offered to them, besides impacting oral health outcomes. For that reason, many educational institutions and faculties around the world are concerned with improving, more and more, their teaching methods. In the literature, we can find several reports of these experiences (1–4).

However, the implementation of new methodologies and "new ways of teaching" may also entail new "demands" for the institutions and also for the people involved (students, instructors and staff). The improvement and modernization of the educational infrastructure, and a greater dedication on the part of academic staff to develop and improve the educational strategies, represent important economic resources that are spent or invested but are commonly unnoticed or underestimated (5). Consequently, there are not habitually described in the literature.

In this context, some research pipeline has been dedicated to bringing relevant and robust contributions to this area. The Initiatives for Undergraduate Students' Training in Cariology (IuSTC) are one of them. They have brought together a group of researchers committed to improving dental education on their topic of interest, Cariology and a desire to transform education through research.

As part of these initiatives, in this thesis, we will address different aspects related to a specific educational activity originally proposed to be implemented in 2009 at the Dental School of the University of São Paulo (FOUSP) in the Pediatric Dentistry Department (6). Then it has been tested and replicated in other universities worldwide as part of a multicenter randomized trial from the IuSTC group – (Initiatives for Undergraduate Students' Training in Cariology) IuSTC01 (7,8), and different nuances could be explored. The main protocol was approved by the Ethics in Research Committee (CAAE 39632614.0.0000.0075) (ANNEX 1) and it is already published. This work is also part of a large project mainly supported by the National Council for Scientific and Technological Development (CNPq - 400736/2014-4). It made this multicentre trial financially possible and permitted the close collaboration of one of the researchers who inspired this project, Prof. Kim Esktrand, a pioneer in educating caries detection.

Studies like the present ones can help to raise awareness about different aspects related to an educational activity implementation, including the monetary aspects of the teaching activities currently used for dental undergraduate education, which is so scarcely remembered. Estimating costs makes it possible to help decision-makers in education invest better in the (scarce) resources available (9).

It was decided to divide this thesis into chapters to explore findings related to the main protocol properly and to organize the description of data related to different aspects raised during the conduction of this large-scale study. In Chapter I, we will debate aspects of implementing this multicentre protocol. We will describe the main difficulties faced by the universities that participated in the IuSTC-01 trial and how that hitches were overcome.

Chapter II brings a comprehensive and analytical overview of the learning outcomes of the educational strategies compared to the IuSTC-01 multicenter study. The chapter also presents the effects (impact) of the teaching methods on the students' theoretical and practical performance across different contexts and centres evaluated.

Chapter III delves into a detailed examination of the resources (ingredients) required for implementing the new teaching strategy in the precursor centre and how valued they are. The cost analysis performed in this chapter considered all inputs necessary for developing and delivering the teaching methodology in the precursor centre. Those results served as a reference for further cost estimation in the other centres presented in Chapter IV. In this last chapter, we added a full economic evaluation of the educational intervention and its cost-effectiveness.

Finally, Chapter V represents a contribution that the COVID-19 pandemics brought to this large project. It describes some adaptations necessary to apply this teaching methodology during the pandemic. Given that the sanitary situation in the universities did not allow for the continuity of face-to-face activities, this chapter describes the modifications made to apply the methodology in virtual or semi-face-to-face education models and how these changes impacted the overall costs of the proposed activity.

The sequential contributions of each of these chapters aim to bring out important answers to the questions raised about the effectiveness and investment in the proposed educational activity. It may also contribute to the dissemination of the activity and its benefits and address those points in which it can be further improved.

2 CHAPTER I: IMPLEMENTING AN ACTIVE LEARNING STRATEGY IN TRAINING DENTAL STUDENTS FOR CARIES DETECTION: CHALLENGES AND REFLECTIONS OF IuSTC STUDY, A PIONEER MULTICENTER STUDY IN DENTAL EDUCATION

ABSTRACT

This paper aims to describe the challenges and difficulties faced by institutions that implemented an innovative pedagogical strategy for training undergraduate students on caries detection and to share the insights gained during the organization and execution of a multicenter pioneer study in dental education (IuSTC study01). The educational strategy proposed by the @IuSTCariology (Initiatives for undergraduate Students' Training in Cariology) research group is an association of conventional learning methods with "more active" educational resources, including a tutored theoretical-practical training with the evaluation of images and extracted teeth, using the preclinical laboratory. A core protocol considering centres' particularities guided the implementation of the activity in different institutions. A special sheet was developed to collect difficulties predicted in each centre context. Later, the same form structure was used to have the difficulties noticed during the implementation phase by each centre coordinator. Besides, a moderator (neutral researcher, not related to the centre) also participated as an observer in the implementation of the activity and registered difficulties that they noticed. A questionnaire about coordinators' impressions of the implementation and the activity was also used. From 16 centers estimated to be included in the study, besides the coordinator, 10 universities indeed participated in the trial (5 Brazilian and 5 international centres). Those who were not included reported operational difficulties in having the activity included in the curriculum at that moment. The most observed difficulties were issues related to students' motivation (50%); materials arrangement (40%) overall planning (30%); lack of infrastructure (30%) and insufficient human resources (20%). All participating centres conveyed that this experience brought significant improvements to their institutions and encouraged the application of active methodologies after that. It is concluded that implementing a new active-learning methodology brings challenges of infrastructure, technical/human resources and student involvement, allowing, on the other hand, gains that will be, for the institutional and staff engaged, apart from the educational effects that the activity can bring.

Keywords: Multicenter Studies as Topic; Education, Dental; Active Learning; Dental Caries

2.1 INTRODUCTION

In dental education, essential topics provide the basic knowledge and need to be very well explored with the students and constantly reinforced during their undergraduate training. Cariology is one of these relevant topics. Indeed, dental caries is still the most prevalent oral disease affecting people of all ages and all over the world (1). Therefore, the students must become competent at caries diagnosis by collecting, analyzing and integrating data on signs and symptoms of dental caries and assessing caries lesion activity status (2). Besides such competencies, training them in caries detection will be a requirement to choose the best way to intervene in the disease process and make them feel more confident in providing the best possible dental care to patients (3).

A significant interest in identifying how Cariology is taught in the different universities in different countries has been noticed, aiming both to understand current teaching conditions (4-7) and encourage consensus and unification of the taught contents (8-10). Nevertheless, no concerns about the strategies to learn this consensual content have been expressed. On the other hand, it is imperative to understand that the curricula should be appraised and the "way" that the content is delivered to the students. Appropriated teaching methodologies for Cariology are needed besides following strict educational requirements.

Lectures has still been the most used manner to teach topics related to Cariology in the universities (9). Nevertheless, such strategy may not be enough for the development of the students' skills for caries detection, since just to receive theoretical knowledge does not provide the opportunity to the student to apply that knowledge (11), and without a practical application experience, learners may struggle then to use it for real-world situations (12). Student-centered teaching approaches have been considered to be better than traditional strategies in increasing students' engagement and promoting a deeper understanding of the contents (13). Their introduction had grown recently and motivated the amendment of many higher educational programs, including medical and dental schools (14,15).

In this context, a new strategy to be used when teaching Cariology, more specifically, focused on developing students' skills in caries detection, has been used and tested since 2009 in the Dental School of the University of São Paulo in Brazil

(FOUSP). This innovative strategy is mainly based on an active-learning purpose (16), showing positive preliminary results in the origin centre (16). Since then, other national and international educational institutions got interested in using and testing this methodology, resulting in a new collaborative research group, the IuSTC Group (Initiatives for Undergraduate Students' Training in Cariology) (17). This group was initially established to improve caries detection training, develop students' skills to work on other topics related to dental caries methods, and provide high-quality content to dental students.

As its first project, the IuSTC Group projected a multicenter randomized controlled trial (MRCT) to compare two educational strategies for teaching undergraduate students about caries detection (18): a conventional passive learning approach (the didactic lecture) and the new purpose of a theoretical-practical strategy, using active learning educational resources, such as small-groups discussions, laboratory simulation training and immediate feedback from tutors (16,18). This multicenter study would potentially permit data collection from different university populations, different geographic regions, and even different cultural contexts, increasing the external validity of the educational strategy (19). Furthermore, researchers with similar interests and skills could share experiences and work together to improve the quality of evidence in the dental education field.

On the other hand, the implementation and execution of a multicenter trial, such as this one, is quite demanding (20). It is also common to face some troubles during the different phases of the study (21). The experience with the IuSTC multicenter trial was not different, and we can say that many challenges were identified throughout its execution. Problems that arose during the planning of the study or any difficulty encountered in its posterior implementation brought essential lessons for the research team that we believe are important to be discussed in a paper. To the best of our knowledge, other studies like this one could not be found on dental education. Therefore, our purpose is to share our experience and describe not only the problems but also the strategies that were adopted to overcome them. We believe other investigators or even interested faculties can be benefited from foreseeing possible complications in conducting multicenter studies and/or implementing new learning strategies and may be to delineate strategies to avoid having the same implementation barriers.

2.2 METHODS

This study could be considered a case study. Similar to other areas like social sciences, case studies have been used to identify social or political situations, to explain them and eventually apply them to similar contexts So, the present paper will focus on the reports from a multicenter study about the difficulties faced by the different universities in implementing a new teaching methodology for dental students, as part of a randomized controlled trial. These results were not the primary outcomes for this trial, which will be published separately elsewhere.

The methodology used in the trial was conceived and first developed in a university, in Brazil, and planned to be replicated in other local and international universities. Then, the coordinator centre selected, intentionally, different locations that could represent different institutions in the same country and other institutions in different parts of America and other continents of the world. This study will describe what happened with the different centres initially selected, as well detail difficulties reported/noticed when planning and implementing the study in each of the included centres.

ETHICS

The study protocol was evaluated and approved by the Ethics in Research Committee (CAAE 39632614.0.0000.0075). The FOUSP, as the coordinating centre, was responsible for submitting the required documents, obtaining the permissions and handling all the initial bureaucratic issues. It is essential to underscore that, for being an international study, each one of the institutions involved in the trial received the approval of their local Review Board.

IUSTC TRAL DESIGN

A two parallel arms trial design was chosen to determine if different methods of teaching Cariology in undergraduate education would influence the clinical performance of students in detecting caries lesion (18). Then, the participants would be randomly divided into groups according to the educational strategy that they would be exposed:

- Without training: the students were exposed to a didactic lecture. The lecture was focused on caries diagnosis, signs and symptoms related to caries lesions, caries lesions assessment and other issues related to decision-making. ICDAS (International Caries Detection and Assessment System Index) was also discussed as a helpful tool for detecting caries lesions (22). Clinical examples were shown as a complementary part of the theoretical exposition.
- Training: the students were exposed to the same lecture and sequentially participated in innovative theoretical-practical training for caries detection. The training was performed in a preclinical laboratory. The students were divided into smaller work peer groups, and each group had the participation of at least one or two tutors. These tutors projected some images and clinical cases on the screen and then stimulated a debate about caries diagnosis and treatment options with the students. Finally, the students assessed a sample of extracted teeth presenting all stages of caries lesions and scored them according to the ICDAS.

At the end of the teaching activities, both groups were evaluated regarding knowledge acquisition and practical skills for caries detection. Those educational effects were evaluated as primary and secondary outcomes to estimate the impact of such new activity.

CENTRES – SELECTION

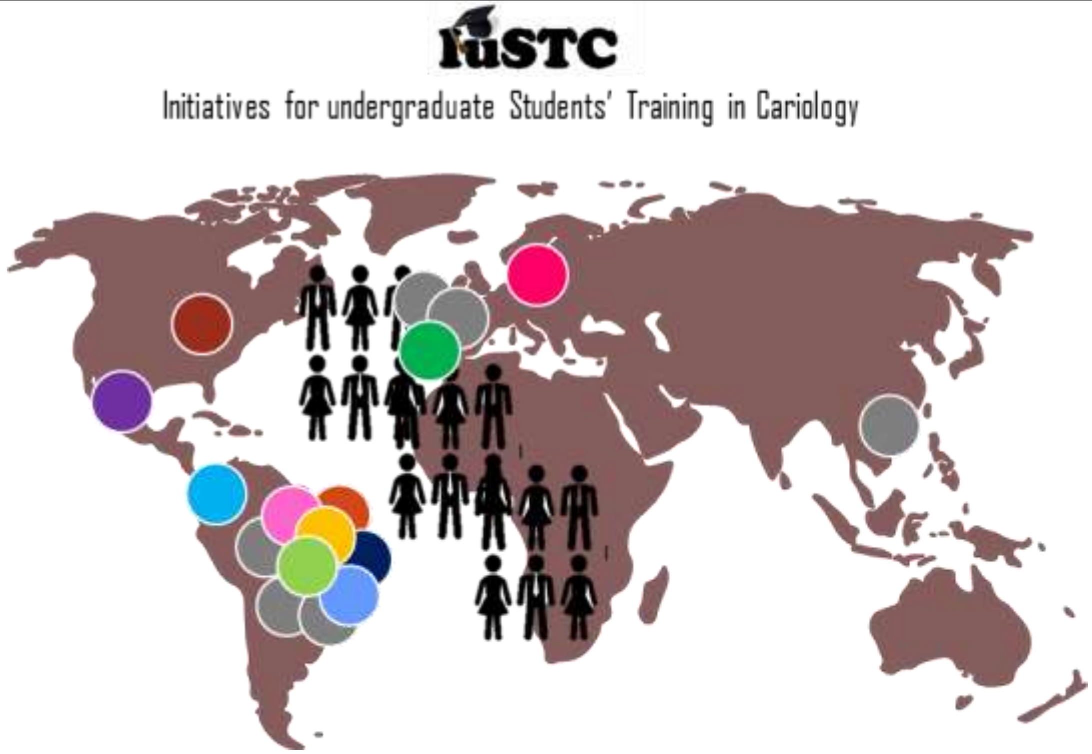
The centres were selected by convenience but also intending to reach a representation of different parts of Brazil and, in a second view, being set in different continents in the world (Figure 2.1). The Dental School, University of São Paulo, located in São Paulo Campus (FO-USP), was the coordinator centre.

In Brazil, it was selected at least one participating centre in each of the five Brazilian regions. All them were Federal Universities, with the exception of those in São Paulo State, which were administered by State. In Southeast and South regions, we selected three and two institutions, respectively, with different internal and regional characteristics, given the higher number of institutions in such areas. They were: Federal University of Amazonas -UFAM (North), Federal University of Piaui- UFPI (Northeast), Federal University of Mato Grosso do Sul – UFMS (West-Centre), Federal University of Santa Maria – UFSM (South), Federal University of Pelotas – UFPel(South), University of São Paulo, Campus Bauru (FOB-USP), State University of São Paulo, Dental School, Araçatuba, SP (UNESP-FOA).

Regarding international centres, we first selected some representatives in the Americas, with different centres in Latin America. Then, we selected Universidad de Guadalajara (Mexico), Universidad El Bosque (Colombia) and Universidad Católica/ Facultad Autonoma de Asunción (Paraguay). Then, other continents were covered: Europe by the University of Copenhagen - Dinamarca, University of Dundee – Scotland, University of Sheffield -England, University of Porto- Portugal, Asia by The University of Hong Kong. A centre in North America was also included after the preliminary inclusion of these first centres, described in the protocol (18).

The invitations for the participation of the centres were also guided by previous contacts between coordinators and/or interest in incorporating the activity to be tested in the respective institutional core of activities. Unfortunately, we could not include an African centre during the study planning.

Figure 2.1 - Location and number of participating centres included and that effectively completed data collection



INSTITUTION	CITY-COUNTRY	YEAR OF INCLUSION	INCLUDED PARTICIPANTS N (%)
University of São Paulo	São Paulo-Brazil	2009-2015	361 (30%)
Federal University of Santa Maria	Santa Maria-Brazil	2015	112 (9%)
School of Dentistry of University of São Paulo	Bauru-Brazil	2015	88 (7%)
Federal University of Piauí,	Piauí-Brazil	2015	119 (10%)
El Bosque University	Bogotá, Colombia	2015	76 (7%)
University of Guadalajara	Jalisco, Mexico	2015	38 (3%)
Federal University of Mato Grosso do Sul, Brazil	Campo Grande-Brazil	2016	35 (3%)
University of Copenhagen	Copenhagen, Denmark	2017	70 (6%)
University of Porto	Porto, Portugal	2017	137 (12%)
Federal University of Pelotas	Pelotas-Brazil	2017	49 (4%)
Indiana University School of Dentistry	Indianapolis, USA	2020	105 (9%)
		TOTAL	**1190 (100%)**

Grey circles represent the centers that could not complete the implementation.

Source: The Author

IMPLEMENTING A MULTICENTER TRIAL

As pointed out, this methodological framework was carried out in the precursor centre (FOUSP) and replicated in the participant's centres. The centers recruited participants between 2009 and 2020 and the whole process on implementing the educational strategy consisted basically, of four main phases that are described ilustred in Figure 2.2 and we detail below.

1. *Preparation of instructional materials (120 minutes)*

   In this phase, the research team (in consensus) elaborates the students' evaluation sheets and selects the natural extracted teeth that will be used for the laboratory training (phase 4). An evaluation kit is prepared, with teeth presenting all possible ICDAS scores. The correct classification is registered in a key answer sheet that will be used as the reference standard.

2. *Tutors' training and calibration (90 minutes)*

   A laboratory training is carried out with the collaborators that will perform as tutors in the teaching activity, the application is exactly the same as how it will be carried out with the students later. Tutors generally were postgraduate students.

3. *Didactic Lecture (60 minutes)*

   Carried out in person, by a calibrated Professor that uses conventional audiovisual resources in a classroom.

4. *Practical-laboratory training (90 minutes)*

   Workshop training activity, performed only with students of the Training group, is carried out in a laboratory equipped with dental lamps and air/water syringes. Students were asked to evaluate the teeth and simulate all the conditions that could be found in the clinical environment. After evaluating the teeth, the tutors guided a discussion with the students and gave them immediate feedback about the corresponding scores to each tooth. After that, they are evaluated in terms of knowledge acquisition and clinical performance in detecting caries lesions.

Figure 2.2 - Phases of the IuSTC Trial Implementation

Source: The Author.

All the centers that agreed to participate in the MRCT, had to replicate this strategy with their students, maintaining the same sequence and standardization.

After deciding to proceed with the multicenter study, the researchers oh the included center planned all trial phases. Firstly, a core protocol was defined and then discussed with the coordinators to guarantee the feasibility of its implementation. An opening meeting was carried out in 2015, led by the coordinating investigator to explain the rationale of the study, its procedures, and its goals. In this meeting, it was also expected to understand the individual backgrounds of the participating centres and evaluate the feasibility of the teaching methodology in each of them. All the centres had at least one representative member (principal center investigator) present in that meeting.

After this initial meeting, individual meetings with centre representatives were organized to discuss and plan the details of each local implementation. On such occasions, representatives were supposed to fill in a form about the planning of the study in each center before starting the data collection. In this form they provided information of their institutions that could be important for the implementation process. Based on that, the coordinator center and the designated representative of each centre decided the best way to implement the strategy, aiming to minimize protocol deviations and significant negative impact on primary outcomes collection by considering the centre's particularities. After this planning stage, the implementation by itself was performed.

To facilitate the implementation process for the participant centres and to ensure that the research protocol was respected, it was decided that a member of the coordinating centre would accompany the application of the educational strategies in the different centres. The role of this researcher, nominated as "moderator/facilitator" was initially to help the local team to develop the teaching activities (by training and assisting them).

All the supplies and instructional materials were provided in advance by the coordinating center team, including, for example, evaluation sheets, exam keys, clinical images and randomization lists. Besides, for the didactic lecture phase, a basic power point template was also provided by the coordinators and the designated lecturer of each center was orientated to previously present this class to her/his local team of tutors (in order to calibrate them). Materials for the practical laboratory like the sample of extracted teeth to be evaluated by the students, were also prepared in advance by the local team, but always assisted by the moderators. To facilitate this process a detailed tutorial was provided with orientations in respect to the quantity of teeth and the number of surfaces that should be selected, in order to maintain the same difficulty level for students and to guarantee their training with all the severity scores of caries lesions.

DATA COLLECTION

Before and after the implementation, a report was completed by the representatives of each center, where all the difficulties perceived in relation to the implementation process were recorded. This report had a semi structured format and covered different categories, such as, problems related to facilities, instructional materials, human resources and curricular or bureaucratic matters. In addition to that, during the whole implementation and application of the teaching activities, the moderator was also in charge of recording protocol deviations, unexpected adversities or hardships faced by the local team in executing the educational intervention. The information perceived by the moderator was also registered in an individual free report, elaborated at the end of the application.

An extra on-line form was also send to the representatives of the centers, sometime after the application, to inquire them about their impressions/perceptions about the IuSTC method and the long-term effects of the educational activity in the institution. In this third report aspects related to human resources, materials and other bureocratical and curricular features were also asked. The present paper is based on those reports and the next results are categorized according to the different phases of the implementation.

2.3 RESULTS

RESEARCH CENTERS INVOLVED

According to the original protocol, sixteen new centers were supposed to be included in the trial (7 from Brazil and 9 from other countries). Unfortunately, some of them could not be effectively included (N= 6 centers38%) due to varied reasons like financial, bureaucratic or logistical issues (Table 2.1). An extra centre that was not foresee in the initial protocol was the last to be included, in 2020, totalizing eleven dental schools were effectively involved in the trial and considered for the next analysis. Six centers were from Brazil and five from other countries. On Figure 2.1 are displayed more details about the number of participants included per center and their distribution.

Table 2.1 – Institutions that did not complete the collection of data

INSTITUTION	COUNTRY	REASONS FOR NOT BEING INCLUDED	PERCENTAGE (%)
State University of São Paulo, Dental School, Araçatuba	Brazil	Difficulties in incorporating the activity into the curriculum	66.6%
Federal University of Amazonas	Brazil		
Universidad Católica Facultad Autonoma de Asunción	Paraguay		
University of Dundee	Scotland		
University of Sheffield	England	Bureaucracy problems in collecting data with regular undergraduate students	16.6%
University of Hong Kong.	China	Financial Issues. Problems in using the initially received budget	16.6%

Source: The Author.

DIFFICULTIES ENCOUNTERED

Some problems were pointed out by the local team (45%) and others were identified by the moderators (32%). The most observed difficulties among the centers during the implementation of the study were: issues related to lack of motivation from the part of students (50%), lack of materials and arrangement of extracted teeth (40%), difficulties in the overall planning of the teaching activities and distribution of students in the laboratory environment (30%) and insufficient human resources (20%), some curricular and bureaucratic concerns were also present (20%), as well as problems in the calibration of tutors (20%). On Tables 2.2, 2.3 and 2.4 are reported some examples of these difficulties, some real solutions found to minimize these issues, and other strategies that could be useful in further projects.

TUTORS PERCEPTION QUESTIONNAIRE

Centres' representatives were unanimous in stating the experience of participating in the trial brought significant improvements to their institutions and encouraged the application of active methodologies after that (Table 2.5). Most of them reported the changes caused by the MRCT remained until the present days (70%) and had their perception changed after being included in the study (80%).

Table 2.2 – Curricular and bureaucratic difficulties identified by the centres (C) and moderators (M) in implementing the trial.

CATEGORY	IMPLEMENTATION PHASE	ACTIVITY	CHALLENGE	CENTERS N (%)	ADOPTED SOLUTION	POTENCIAL SOLUTIONS
CURRICULAR OR BUREOCRATIC	Development Phase	Planning	Insufficient hours to implement the new activity	C **1 (10%)**	• Negotiating vacant hours with other disciplines	• Restructure the way of organizing the old conventional class (e.g. change a 4h didactical lecture to the combination of activities proposed • To invite the students to come outside their normal class hours. • To offer incentives (e.g. snakcs, juices) during activities if they should be present in extra time classesv
		Preparation of materials	Professor/ students unfamiliarized with the institution	C **1 (10%)**	Prepate tutorials/Record videos to introduce materials and the activity. Working in small groups and adding extra explatnations about unknow topics	•
	Delivering Phase	Lecture	Different phylosofies of teaching caries detection (ICDAS was not taught before)	M M **2 (20%)**	Prepate tutorials/Record videos to introduce materials and the activity.	
		Practical Training	Difficulty in booking the laboratory rooms	C C **2 (20%)**		

Source: The authorv

Table 2.3 —Difficulties related to facilities, identified by the centres (C) and moderators (M) in implementing the trial.

CATEGORY	IMPLEMENTATION PHASE	ACTIVITY	CHALLENGE	CENTERS N (%)	ADOPTED SOLUTION	POTENCIAL SOLUTIONS
FACILITIES	Development Phase	Planning	Distribution of students	C C C **3 (30%)**	• Using different spaces, increasing vigilance to avoind groups contamination • Organizing all activities in a same controlled big space • Controling the time for activity deliverying to avoid contamination	• Stratified randomization for different stratum/group pf students which have to be sepaated to guarantee the balance between groups.
	Delivering Phase	Practical Training	Limited space for students	M/C M M **3 (30%)**	• Division of students in groups (caution to not compromise the randomization and real-world representativeness)	• Use of different laboratories or classrooms
			Lack of dental lights	M/C M **2 (20%)**	• Use of portable lamps	•

Source: The author.

Table 2.4 - Curricular and bureaucratic difficulties identified by the centres (C) and moderators (M) in implementing the trial.

CATEGORY	IMPLEMENTATION PHASE	ACTIVITY	CHALLENEGE			POTENCIAL SOLUTIONS
HUMAN RESOURCES	Development Phase	Preparation of materials	Limited people to help to prepare the materials	C M 2 (20%)	Attempts to recruit and train potential tutors, from continuing education courses, geral dentists. Etc.	• Engage multidisciplinary staff
		Tutor's Calibration	No time for training and calibrations	M/C M/C 2 (20%)	A more strict plan of all supporting actions provided by the coordinator centre	• Definition of the actors' roles in different centres
	Delivering Phase	Didactic Lecture	Insecurity of the lecture content	M M 2 (20%)	Prepate tutorials/Record videos to introduce materials and the activity.	• Stricter plan of all supporting actions provided by the coordinator centre • Prepate tutorials to introduce the activity.
		Practical Training	Lack of tutors for the training	M/C C 2 (20%)	Reduce the numer of students per delivering and using the same tutors	• Engage multidisciplinary staff • Create a team of tutors and replicate the traiing • Using graduate students/PhD, MSC, specialization as staff/tutors • Incrase the number of students per workgroup to use less tutors • Use interchangeable teams among close intitutions
MATERIALS	Developing Phase	Preparation of materials	Lack of extracted teeth	C C C C 4 (40%)	Use na interchangeble sample among institutions	• Prepare a new kit • Call for donation of human teeth • Create a banck of teeth
OTHER DIFICULTIES	Delivering Phase	Lecture	-			-
		Practical Training	Motivation of students	M/C M M C M/C 5 (50%)	To offer incentives (e.g. snakcs, juices) during activities if they should be present in extra time classes.	

Source: The author.

Table 2.5 - Principal center investigators' opinions about the IuSTC teaching methods and the implementation process.

QUESTION	ALTERNATIVES	FREQUENCY (N)	PERCENTAGE (%)
After participating in this Multicenter Study, did you change your perception regarding the teaching methodologies?	a) Yes b) No	**8** **2**	**80%** **20%**
In your opinion, has this educational strategy caused any significant changes in the institution?	a) Yes, it caused improvement b) Yes, it caused worseness c) There was no significant changes	**10** **0** **0**	**100%** **0%** **0%**
After participating in this Multicenter Study, did your institution make any changes in the teaching methodologies applied for undergraduate students?	a) Yes, and the changes remain today b) Yes, but the changes were only temporary c) there was no change	**7** **3** **0**	**70%** **30%** **0%**
In your opinion, what is the feasibility of applying this training activity in Dentistry, in general?	In a scale 1 to 5 Where: 1=No feasible 2=Low feasible 3=Medium feasible 4= Feasible 5=Very Feasible	 **0** **0** **0** **1** **9**	 **0%** **0%** **0%** **10%** **90%**
Do you believe that the assessment tool used in the IuSTC teaching strategy (ICDAS index) is a good tool for teaching cariology in undergraduate education?	a) Yes b) No	**10** **0**	**100%** **0%**
	TOTAL	**10**	**100%**

Source: The author.

2.4 DISCUSSION

This study described the experience of a multicenter randomized controlled trial and the process of implementing an educational strategy for teaching caries detection to undergraduate dental students. Implementing any new teaching method is very challenging for educators and learners. In our multicenter study, the first challenge was leading with centres that were included but could not complete data collection. Indeed, introducing new ideas may create several kinds of resistance (22). Even including a convenience sample, contextual and subliminal challenges may have risen, and this is also important to understand the validity of implementing an innovative idea.

In our case study, most incomplete data collection was due to the impossibility of coordinating the activity and the current curricula or undergraduate course schedule. We understand these findings reflect a certain level of resistance (even non-declared or subliminal) or a delay in incorporating new ideas in formal dental education. This observation brings out an essential understanding of the social/institutional context (23) we would like to explore when designing a real-world study and testing the educational strategy precisely in this scenario. Besides, it reinforces the need for bringing together traditional knowledge and modern scientific knowledge in an interdisciplinary approach to promote development challenges and to adaptation and dissemination of suitable innovations (23).

Other concerns and difficulties could be detected from the planning phase to the implementation phase. Recognizing and leading with these struggling issues is essential to minimize the negative impact on educational outcomes and/or learning goals. Furthermore, sharing attempts to overcome difficulties or propose new solutions is exceptionally valid for saving time and effort in further initiatives. We believe this paper is an important contribution of the IuSTC group for dental education, guiding both further MRCT and implementation of new educational activities for engaging dental students in active learning.

On the other hand, our qualitative analyses of centres' representatives pointed out good aspects related to implementing the new activity. Faculties implementing the new educational activity perceived the learning pathway as beneficial to the students and tended to incorporate them after finishing study data collection. Even facing difficulties (some of them not able to be solved before/during implementation), the lecturers seem to recognize the benefits and adapt the activity to their teaching routine. Although we should consider these interviewees naturally present a biased point-of-view since they are inclined to participate in the study, we must also point out the importance of these actors in initiating and continuing the activity in the institution and among their peers. Some frameworks regarding the implementation of scientific evidence demonstrated an additional interplay of context and facilitation besides the knowledge/evidence itself (24–26). Then, even more than positive feedback about the implementation and the activity itself, we should understand the staff feedback as a crucial mechanism of facilitation and potential for continuity and dissemination of the idea – enabling others to do it the same way (27). The magnitude of such impact should be explored in further studies.

Specific difficulties and related potential solutions will be discussed in the next paragraphs of this chapter. They were divided into common categories of problems detected during the study/activity implementation.

CURRICULAR AND BUREAUCRATIC ISSUES

At first, some obstacles may be encountered in receiving ethical approval for all the centres. To avoid these problems, the coordinating centre (FOUSP) was responsible for the ethical approval part, and the other centres were registered as co-participants/collaborators in the research protocol. This strategy did not exclude them from dealing with individual local approvals at each centre. In some centres, it took several months. In one of them, it was the reason for not concluding the data collection on time. Bureaucratic hitches are constantly pointed out as a prevalent difficulty for multicenter and international studies (21,28). They can delay the recruitment of participants and even make the application in new centres unfeasible (28).

One perceived challenge related to curricular issues was adjusting the new learning activity to a previously structured course schedule. As each discipline/lecture has a specific amount of hours to complete all the content that must be worked with the students, some negotiations or rearrangements were required. Since it is a single activity implementation (and not a curricula restructuring, for example), reconciling the schedule may be challenging. A local team of investigators proposed a way to solve this problem. An attempt to negotiate vacant hours with other disciplines just to be able to perform the activities, but in case it was not possible, the other way to solve the problem would be to invite the students to come outside their regular class hours.

Given the frustrating attempt of receiving extra hours to teach, the second option was adopted in such a specific centre. Extra thought was demanded in this specific case to avoid compromising the response rate and the representation of the real-world education we are interested in this study. Several studies exploring caries detection with undergraduate students may overestimate the results since intentionally convenient samples were selected (3). Usually, these students are those who are more dedicated and prone to achieve good results. This scenario was not desired for this protocol. That is why the coordinator centre carefully monitored the randomization and data collection. All students assigned to the class were considered for the randomization, and even being an extra class, a high response rate was achieved (91%). The centre coordinator prepared special incentives to motivate students and offered them snacks, juices, and cakes. These actions were used as positive reinforcement and not advertised in advance as a type of interchange.

Another strategy is restructuring the way of learning. Actually, it was the experience of the coordinator centre (16). The longer lecturers (around 2h for caries detection) were remodeled and permitted complete activity incorporation. Usually, this strategy is feasible because traditional lecturers are used to being long (29) and then extra space may be created since the innovation is the idea.

Other struggling circumstances may be caused when the activity is implemented for the first-years students. First-years students may be a novice in preclinical trainings. They could not be familiarized with the laboratories and the instruments used in the learning activity. This problem was easily circumvented in the local centre, since students were working in small groups and assisted by tutors. Other strategies for preparing students for preclinical activities can also be planned and implemented (Table 2.2). Where identified this difficulty, students learned rapidly and became more and more familiar with the instruments during the training activity. Final students' performance is not necessarily influenced by previous experiences or previous knowledge (30), suggesting these initial difficulties, as was evidenced in this study, may not be a big issue when completing their laboratory activity.

FACILITIES ISSUES

It is normal to find differences in facilities in the different dental schools. Local facilities may be influenced by the number of students registered, the geographical region and local investments in high education. In this study, we observed that the infrastructure of some laboratories where the activities were performed significantly varied. Despite such variation, the implementation was not undermined by that, nor the results as described in Chapter 2. For example, in one of the centres, the laboratory was not equipped with dental lights for all registered students. As a solution, students used portable lamps they brought by themselves (or could have been provided by the centre) to complete the teeth examination. Issues related to the physical infrastructure of buildings must be considered when implementing a new educational activity. They can influence students' behaviour and perception of the whole learning process, but, at the same time, they cannot be considered that crucial to determinate the students' performance (31).

Another point to be considered here was that the students from the two groups (control and test) needed to be evaluated immediately after the teaching activities. The initial design in the coordinator centre was done considering all students from both groups in the same space (same laboratory). The two groups simultaneously performed different activities independently, and no "contamination of the groups" was expected among them since the complete environment was controlled. Good logistic strategies had to be planned to allow the students not to wait too long to perform their assessments and because we had to avoid possible "contamination of the groups" (32). Sometimes, different laboratories had to be used, or students from the same class/generation should be separated. These methodological options generated extra vigilance to minimize the impact on the study's internal validity. If students from the same generation were separated, stratified randomization was done, and each part of the generation was treated as a stratum. Then, a different randomization list was generated for each stratum, guaranteeing the balance between groups inside them.

HUMAN RESOURCES ISSUES

The coordinator centre was one of the largest dental schools in Brazil and is characterized by having a lot of undergraduate and graduate students collaborating with the development of teaching-learning activities and research. In the beginning, we expected adaptations regarding staff would be the most needed alongside the centres. Indeed, some of the other centres reported insufficient people that could act as tutors in the training workgroups. The difficulties reported/detected regarding that are even less than expected. The moderator also pointed out this lack of human resources in more than 2 centres, which influenced how the teaching method was carried out. In some cases, according to the number of students, it was necessary to divide the class and applicate the training several times, considering all prerogatives to minimize the negative consequences, as described above. Other centres had to organize the students and form training groups with more participants per tutor. Another solution found was to create a multidisciplinary team of tutors, engaging faculties from different origins that could act as tutors in such concurrent learning activities. Other attempts to engage tutors may be found in Table 2.4

We consider that having tutors in this teaching activity makes a difference because being in small groups stimulates students' participation. The tutors are essential to support the students throughout the training and guide the activity in the expected pathways. They may also create a more relaxed and chatting environment than observed in the one-and-one learning (33). When the interaction between tutors and students is harmed, the distinctive "Personal Tutoring" active resource can be lost (33,34). In a previous study, an effective tutor's role in teaching-learning was demonstrated to increase students' motivation and promote more significant learning. Therefore, all initiatives to engage staff to work as tutors in this learning activity are valid for achieving positive outcomes.

Tutors training is another issue to be considered. A heterogeneous group of coordinators are formed given the differences in the scientific and professional background of faculties involved in different centres. The coordinator centre worked to minimize the challenges created by these different backgrounds. Then, researchers from the coordinator centre helped train and calibrate tutors, supporting the preparation and delivery of the activity. However, some difficulties were associated to some failures in such support strategy (Table 2.4)., These occurrences were isolated and did not require any solution, but for further implementation, a stricter plan of all supporting actions provided by the coordinator centre, as well as the actors' roles in different centres, should be previously determined and contracted (20).

MATERIALS ARRANGEMENT

One of the significant challenges of conducting a multicenter study is maintaining adequate standardization across the centres and guaranteeing an equivalent experience for the participants in all study phases (35,36). To minimize problems related to the preparation of instructional materials, the coordinating center provided those materials used for instructional purposes (tutorials, instructional sheets, OMS probes for the hands-on training) or for guranting the protocol development (evaluation sheets for students, randomization lists).

The availability of human teeth for training was the main concern regarding materials for the activity. The coordinator centre organized different kits of extracted teeth donated by the local Human Teeth Bank and contributed to other centers providing this material for the planned activities. For the international centers, it was not possible to transport human teeth due to legal requirements or specific guidelines for dealing with biological materials in the different countries. In consequence, the international centres had the extra challenge of creating, in record time, a new kit/sample of teeth following the same standardized steps and levels of difficulties for the practical assessments. Given this difficulty, a sustainable solution should be etsimulated in different centres to guarantee further applications. Some other possible initiatives can be found in Table 2.4.

OTHER DIFFICULTIES

The concern about improving health professionals' education is imminent (37). Instructors always try to motivate students, but although innovative training is exciting and normally engages the students, some challenges were observed concerning the students' motivation and adherence to the activities in some centres. This issue was the most frequently reported by the centres. In some centres, as discussed before, the teaching strategy was held out of the class time and was offered as an official but "extra" activity. This choice may probably have affected some students' participation because there were students who wanted to participate. Still, they were not able since they had other academic obligations at the same time. It has been observed that some students were "tired", which could affect their ability to focus and interact with all the stages and dynamics of the training activity. As an example, we can cite that in one of the centers the activity was performed just before an exam from another discipline, which contributed to students', non-attendance. This situation, in accordance with other study in the pharmacological education field, is commonly observed (38). Despite that, response rates were high, varying from 74% to 100% in the different centers. Additionally, students' feedback about the whole teaching-learning process were registered.

Other issue that could be a problem, but it was not at the end, was the fact that, the randomization lists were performed per classroom, considering all the students of the participant class, even not knowing if all of them would be present the day of the activity or if they all will accept to participate in the study. The randomization was the coordinating center’s responsibility and it was performed in this way to avoid possible delays in starting the activities with the students and loss student' enthusiasm or make them get tired before even start.

GENERAL CHALLENGES

A good organization and careful management of the collected data is essential in MRCT (39), because the more data volume, the greater the risk of loss in confidentiality. In this study, it was decided that the coordinating centre would save and protect the data. There are examples of studies that, by performing a self-assessment, such as the one carried out in this study, improved their operations and achieved recruiting goals much faster in their subsequent studies (21). Moreover, the responsibility for monitoring the educational activities in each centre and managing the data collected was of the coordinating centre (FOUSP), guaranteeing the quality of data to produce the final results of this trial.

Apart from the difficulties described, we can cite that the cost is a concern in multicenter trials and also cultural influences can affect the results (35). Any centre representative or moderator did not point out these aspects. Besides that, we can highlight an extra challenge: disseminating the evidence produced in such a corporative effort. Many scientific journals do not accept numerous authors for papers, which could be an issue because, usually, multicenter studies have large research teams and several collaborators in each centre. Looking for alternative journal and formats for publication, as well as using collaborative authorship, as we have being used for the IuSTC group are solutions for that (36,39).

It is concluded that implementing the new teaching methodology brings challenges of infrastructure, technical/human resources and student involvement, allowing, on the other hand, gains that creative solutions can promote. Certainly, methodological problems often exist, especially in large multicenter international trials. Therefore, it is important to identify and discuss these hurdles in a paper to understand the impact of study findings.

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3 CHAPTER II: IS TUTORED THEORETICAL-PRACTICAL TRAINING A HELPFUL APPROACH TO DEVELOPING UNDERGRADUATE STUDENTS'SKILLS FOR THE DETECTION OF CARIES LESIONS? – IUSTC01 RANDOMIZED AND CONTROLLED MULTICENTER STUDY

ABSTRACT

Although traditional lectures have been the most used strategies to teach Cariology, they may not be enough to develop expected dental students' competencies for caries detection. Therefore, during undergraduate education, implementing active learning methods that integrate theoretical and practical skills seems necessary. The IuSTCariology group proposed this two-arm multicenter controlled randomized trial to verify if a theoretical-practical preclinical training activity for caries detection associated with the conventional lecture would improve the undergraduate students' practical skills for caries detection. Undergraduate dental students were recruited from different universities worldwide and allocated into two groups, depending on the teaching method. This theoretical-practical training comprised a preestablished educational intervention using images and extracted teeth and a standardized methodology in small work groups with peers and guided by tutors. The control group, otherwise, did not receive this preclinical training. The primary outcome was the ability to assess the dental surfaces correctly (practical skills). Theoretical skills, decision-making ability and student-centred outcomes were also investigated. Specific tests and forms were prepared for each one of these assessments. Multilevel regression analyses were performed to test the influence of the training on studied outcomes using as levels the assessment (when more than one per student), the student and the centre. Multiple models were proposed to understand the influence of variables possibly related to the outcomes. 31 different classes from 11 universities were enrolled in this study. 1190 undergraduate dental students were included (mean response rate = 90%). Students who participated in the active-learning training activity had, on average, almost 7% and 36%-higher number of correct answers, respectively, when scoring the severity of dental surfaces or assessing its activity caries status, compared to the group was not exposed to that. Additionally, trained students scored highly on the importance of using an index for caries detection and their self-perceived performance on a practical assessment. The activity also impacted students' theoretical skills and competency for decision-making after diagnosis primarily related to activity assessment. These results were adjusted for centre differences and independent of the student's formation level. In conclusion, the theoretical-practical preclinical training positively impacts the students' practical skills on caries detection and benefits the student-centred outcomes related to their performances.

KEYWORDS: Teaching Methods; Experiential Learning; Educational Measurement; Dental Caries.

3.1 INTRODUCTION

Caries detection is an essential topic in dental education (1) since it denotes a critical element in establishing a diagnosis and the accurate prescription of dental treatments (2). Future dentists should be competent at collecting, analyzing and combining data on signs and symptoms of dental caries to state about past or present occurrences of dental caries being needed (3). Then, they should be prepared to make a differential diagnosis between sound surfaces and caries ones, as well staging caries lesion severity and assessing their activity status (3). This aspect becomes especially relevant considering that Cariology is the type of basic content related to many different areas or specialties in Dentistry and is part of the daily clinical routine for dental professionals (4).

Given the practical nature of such competencies, the development of theoretical skills would not be sufficient to achieve them fully. Although many higher education institutions focus on providing complete and comprehensive theoretical content to their students because it represents an important aspect of any learning system, theoretical knowledge solely may not be enough to develop all students' competencies (5). In Dentistry, some professional competencies like this one require a blending of types of training since the non-development of some students' practical skills may eventually cause difficulties in their clinical practice with patients (6). Nevertheless, conventional lectures are still the most used manner to teach students about Cariology (3).

Interactive laboratory activities may systematically provide opportunities for undergraduate students to experience different simulated situations covering a variety of circumstances that they should be able to solve in clinical practice (7). Moreover, practical training makes feasible a higher participation and exchange between students and their tutors in the teaching-learning process (8,9). Finally, such experience contributes to immediate feedback on students' performance (10) and permits prompt doubts solving, improving the educational outcome. Indeed, active learning methods are superior to conventional lecturing in several areas because they enhance students' performance and reduce failure rates (11). Although some initiatives have been used to train students for caries detection, they were primarily isolated actions and/or performed in specific and small groups of students. Merely analyzing such results may be biased since convenience samples may overestimate the results found in the real-world (12). Within this framework, a constant evaluation of the teaching methods and their learning outcomes in different contexts is imperative (13). Despite the imminent concern about the need to improve professional's education (14), we still observe that educational institutions are not properly aligned in how the contents have been delivered to their students (15), which could finally affect the final professionals' formation.

This study, proposed by the collaborative research group: Initiatives for Undergraduate Students' Training in Cariology (IuSTC), is undoubtedly a pioneer enterprise because it is designed to present a multicentre nature (as discussed in Chapter 1), bring an actual comparison between an alternative (active-learning based) intervention to a traditional one, and include students in their "real-world" (not intentionally selected). Understanding the impact of a promising alternative activity for dental education is essential before promoting its dissemination and inclusion in different undergraduate and continuing education curricula. Moreover, it can also bring significant benefits for the learners, the universities, and society as a whole.

3.2 METHODS

The research protocol for this multicenter study: *"Impact of a tutored detection of caries lesions: multicenter controlled and randomized study"* was approved by the Local Ethics in Research Committee (CAAE 39632614.0.0000.0075) (Annex 1) and published elsewhere (7). All the educational institutions involved in the study approved the protocol in their local ethics committees or correspondent authorities.

This manuscript is focused on describing and discussing findings related to the educational learning outcomes, including the primary outcome (students' practical skills) and some of the secondary outcomes expected to be evaluated, basically grouped as theoretical skills, decision-making abilities and student-centred outcomes). This report was prepared using the Consolidated Standards of Reporting Trials (CONSORT) and, as we are describing a trial of educational interventions, we also used the Guideline for Reporting Evidence-based practice Educational interventions and Teaching (GREET) checklist (17) (ANNEX A).

TRIAL DESIGN AND THEORY

This controlled, randomized, multicentre study mainly compared two teaching methods for caries detection implemented in a real-world teaching-learning context. The intervention of interest (alternative intervention) was a new active learning teaching strategy involving tutored theoretical-practical training for caries detection using visual inspection. As the control group, we chose the most commonly used educational strategy in Cariology, the didactic lecture (conventional teaching strategy (7).

We proposed a pre-established tutored activity, designed and preliminary tested in the coordinator centre (16). It is essentially based on a small peer work group in the alternative intervention. We adopted an active-learning approach since the activity was supposed to be guided by the students' answers which were constantly mediated by the tutors to guarantee the complete content exploration. Moreover, the tutors constantly stimulated interactivity, continuous feedback and doubt-solving.

EVIDENCE-BASED PRACTICE CONTENT

Both interventions compared in this study were designed based on the best available pieces of evidence in caries detection, which was our background. Additionally, topics related to different aspects the undergraduate student is supposed to have knowledge, competencies and be familiar with guided the choice of the topics for these interventions (3). Although different methods for caries detection have been commented on, an emphasis was placed on visual inspection, given its performance and clinical relevance demonstrated in recent systematic reviews (18,19). Besides, a proposal of using an index for scoring caries severity was also based on the best available evidence (19) and suggestion of the use of the most used international system for doing that in a friendlier way to be communicated (20) and appropriately used even for less experienced students (21). Furthermore, evidence on assessing activity lesion status was also presented, despite being less robust, showing its relationship with caries progression and clinical decision-making (20). Finally, an evidence-based decision-making chart was presented linking the caries assessment (severity and activity status) and therapeutical approaches (22,23).

LEARNING OBJECTIVES

Learning objectives were defined according to knowledge and competencies to be acquired according to the European Core Curriculum in Cariology for Undergraduate Dental Students (1). In the caries detection topic, basically, it was expected the student could:

- Differentiate sound tissues from carious ones (caries lesions, in different severities and activity status)
- Classify caries lesions according to different severities
- Properly assess caries lesion activity status (note: considering this is a dynamic clinical status, we assumed the student should be able to recognize features related to the activity status that could be evaluated in the extracted teeth, such as texture, location, and pigmentation.

These competencies were then converted into the primary outcome, described further.

CENTRES AND PARTICIPANTS

The sample was composed of undergraduate students from different dental schools worldwide that were invited to participate. The participant institutions were selected by convenience and all dental students from the chosen classes could be enrolled in the study. The Dental School at the University of São Paulo (FOUSP) performed as the coordinating center (precursor) and in order to have a national and international representation, centers from different parts of Brazil and various continents around the world were also selected (see chapter I).

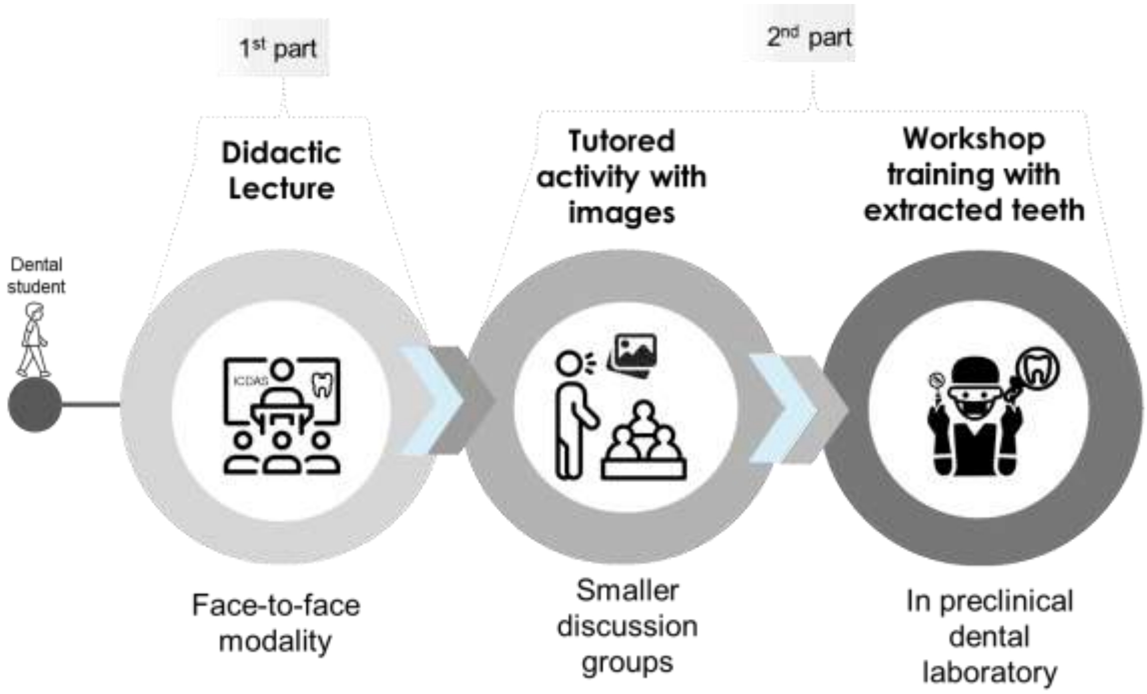
The centre coordinator was responsible for organizing the implementation of the study in his/her centre and defined which class of students would be included. Afterwards, to consider the students' formation level, students were categorized into first and last-year students. The coordinator invited the students to participate in the study and explained the educational activities would happen independently of their acceptance. At the end of the assessments, they returned the signed consent term in a box if they agreed to participate in the study. In another, they returned the unidentified assessment sheets to guarantee no punishment or harm if they did not want to participate.

INTERVENTIONS - EDUCATIONAL ACTIVITIES

The strategies

All participant universities carried out the teaching activities following the same application format (Figure 3.1). Some minor adjustments were necessary, as described below, but they did not interfere with the main design of the study.

Figure 3.1 – Original application format of the theoretical-practical training strategy for dental students



Source: The author.

A traditional didactic lecture was prepared for both groups including basic concepts of caries lesions formation, their clinical characteristics and their importance for diagnosis and treatments. Important concepts of caries detection and the use of ICDAS as a tool for aiding caries detection was also explored, as well as, decision-making process based on the diagnosis. Students allocated to the control group were evaluated immediately after this lecture. A model was used as reference but each centre was responsible for preparing the lecture giving the content items mentioned above and the evidence which mainly supported the content, pointed out in a previous topic in this manuscript.

Students allocated to the test group participated in the additional theoretical-practical training in a preclinical laboratory and were finally evaluated at the end of this activity. During the laboratory training activity, the students were divided into smaller groups intending to improve interaction among them. The number of workgroups was defined depending on the number of students per class in each centre. The criteria for the division was maintaining 7-to-10 students per group, which 1 or 2 tutors would lead. The theoretical-practical activity was subdivided into 2 main parts (Figure 3.1). The first stage was based on evaluating and discussing clinical photographs containing different examples of dental surfaces (Figure 3.2a). The photographs represented different clinical conditions from sound sites to severe decays. They had been selected from a pool of images according to their didactical potential and previously scored by reference examiners (lecturers) to permit further corrections among students. These images permit various conditions, which is helpful in this first stage to permit a broader discussion. Nevertheless, pictures had been taken intentionally, so students were probably more prone to be guided to look at a specific part of the surface, and what could be helpful for them at such a stage.

The second stage was performed using extracted human teeth. Lecturers pre-selected surfaces containing all possible ICDAS scores were used. Teeth were distributed in plastic bottles in 100% humidity (Figure 3.2 b, c) and prepared in advance for this activity. Different samples were collected for the training in each centre since more than one group performed this activity simultaneously in the lab. All that samples maintained similar composition and level of difficulty. A tutorial was used to guarantee that in different centres. At this stage, students were not guided by the photographer's eye and reproduced the detection process clinically. We believe these successive steps have been necessary to construct the caries detection process in students' minds.

Figure 3.2 - The tutored theoretical-laboratorial training was performed with the students, by assessing clinical images (a) and extracted teeth (b, c) with different stages of caries lesions

Source: The author.

Delivery and schedule

Initially, all included students (the entire class) received a 60-min conventional lecture. Then, the students allocated to the active-learning laboratory training should also receive the two-stage additional educational activity.

The active-learning activity, which took approximately 90 minutes, first, undergraduate students were supposed to score 30 clinical photographs in these groups according to their severity and activity status. After scoring them, tutors stimulated students to discuss their answers in the workgroup (Figure 3.2a). In the second phase, a sample of extracted teeth (with some marked surfaces to guide the evaluation, as using a dental chart) was distributed in each workgroup. Students were orientated to wet extract teeth and examine them using a mirror, ballpoint probe, and air-drying when necessary, not exceeding 5s (Figure 3.2b). In both phases, tutors stimulated the discussion in small groups, and students were encouraged to say and justify their answers and even to defend their ideas against other different answers. We believe this strategy for discussion may be more helpful for stimulating the rationale behind the free choice for severity scores or activity statuses than giving them the "correct answer" by itself. Doubts and disagreements were discussed during activities involving all workgroup participants and using their divergences as the starting points (Figure 3.3)

For ethical reasons, students from the control group received the same laboratory activity after assessing the isolated lecture effect. Then, we could guarantee the students would not be harmed despite the strategy they had been allocated to. This option permits a very close "real-world" reproduction despite the randomization and the study implementation.

The activity was delivered only once per class of students totalizing approximately 3 hours of duration. In each centre, the coordinator organized the date given the course programme and schedule

Incentives

No incentives were officially given to students, or tutors enrolled in the study.

Figure 3.3 – Active learning method applied in the different centers. During the workgroup discussion, the tutors acted as facilitators to enhance students' learning experience. Engaging in discussion encouraged students to apply critical thinking skills and judge their own and their peers' responses

Source: Images gently donated by the centers

Instructors

The didactic lecture was delivered by the lecturer/staff chosen by the coordinator. We recommended that the professor lecturing the chosen content was maintained and followed the main requisites described above for the content to be worked on.

The tutors in the laboratory training were faculties or graduate students who interacted with the learners during the activity. They were selected and distributed in the workgroups by each coordinator centre. The number of tutors per group also depended on the staff available in each centre. They had been trained and calibrated previously by the coordinators and were supervised by them during the educational activity.

Environment

The learning environments used for these activities were a conventional classroom, for the lecture and preclinical laboratories for the training. According to the physical spaces available in each center, it was organized the students' distribution.

Centre's adaptations and modifications

Minor adaptations were necessary for some centres to make the activity feasible. We can point out some of them: the separation of students at different moments for the activity due to the lack of infrastructure and more prominent laboratories and the use of a different number of tutors and students per workgroup. The complete description may be found in Chapter 1. Nevertheless, all adaptations did not modify the main protocol and were also discussed with the coordinator centre to guarantee the study's internal validity.

Attendance

The assessment was performed on the same day educational activities were delivered. Then, we assumed the students agreed to participate in the study and returned their assessment sheets had attended the educational activity. As the forms were unanimously filled, we could not check the list of students who attended the classroom and laboratory activities. The number of students who signed the presence list was only used for the calculation of the response rate of the study. Then, we considered the number of attendees as invited students and the number of forms received as the number of positive responses.

Monitoring

A representative of the coordinator centre, trained and aware of all critical methodologic aspects of the protocol, was sent to each centre when implementing the study. This researcher was responsible for reporting all protocol deviations, adaptations, and modifications (previously planned with the coordinator centre or not). This information was quantitative and qualitatively used for analyzing and interpreting study findings.

OUTCOMES

A summary of the IuSTC study outcomes is presented in Table 3.1 This chapter will focus on the immediate educational effects of the teaching strategies and the student's perception of the teaching activities. Other endpoints will be included in the following chapters (chapters 3 and 4) or further publications (as the medium and long-term knowledge retention). Each one of the learning outcomes and respective endpoints will be detailed below.

Although the instructional intervention tested here is intended to promote a vector of learning outcomes and aims to improve the overall professional's accuracy for clinical practice, the student's practical skills were defined as the primary outcome of this study. Other outcomes were set as secondary (theoretical skills, clinical decision-making ability and student-centred outcomes).

Development of practical skills for detecting caries lesions (primary outcome)

A practical test was performed using a sample of extracted teeth containing 31-33 dental surfaces to measure the student's practical skills. This assessment was prepared to check the student's practical ability to detect and score caries lesions on pre-selected surfaces. Besides, they were supposed to classify the caries activity status of the surface, considering those characteristics related to the activity status that could be remained in surfaces as pigmentation, texture, opacity and location. Students' correct answers were obtained using a reference standard prepared by expert researchers in caries detection.

Similar kits of extracted teeth were prepared in advance by experienced lecturers and graduate students using a tutorial and a standard methodology to guarantee the level of difficulty of all assessments was standardized, guaranteeing the similarity among centres. During the practical test, students were orientated to simulate the oral environment conditions regarding moisture conditions and the time for evaluating each tooth was standardized in 1 minute. They received a sheet containing tooth schematic draw, and surfaces to be evaluated were highlighted. A maximum of two surfaces per tooth were selected to be assessed. The difficulty level was also considered to maintain enough assessment time in these cases.

Acquisition of theoretical knowledge in caries detection

In a theoretical assessment, the lecturers created a brief 5-question test to assess the learner's cognitive skills and reasoning-contextualization ability. The test was pre-validated in a pilot study of our group (16). It comprised multiple-choice tests and wh-questions regarding the impact of incorrect diagnosis of different clinical conditions (lesions severity). Lecturers also determined the correct answers in this assessment. Each student was assigned a score from 0 to 10, proportional to the number of correct answers.

Ability/Attitude for decision-making after performing caries detection, considering the possible choices

This assessment comprised five clinical images where students had to identify the presence of caries lesions, score their severity and activity status, and decide about their management. Each clinical case was projected on a computer or TV screen, and the students were supposed to complete the mentioned tasks. This section intended to assess the students' competencies for caries detection, including their knowledge, abilities and attitudes regarding clinical conditions represented by each case (24). Clinical conditions were chosen as very representative conditions that students' decision-making would be crucial in clinical practice.

Student-Centred Outcomes

We assessed three different student-centred perspectives as secondary outcomes: self-perceived performance, the importance of using an index for aiding caries detection, and the student's perception of his/her mood after completing the learning activity. This pool of student-centred outcomes may reflect another glance regarding the proposed learning activities. Besides, they could also be related to some educational learning effects explored.

Simple questions were included in a sheet after the learning activity to be answered by the student and assess the first two outcomes (Table 3.1). They should answer these 5 questions using a 5-point Likert scale and a10-point VAS scale to measure these two outcomes (Table 3.1). A 4-Likert-scale associated with a State-Trait Personality Inventory scale (25) was used to assess students' perception of his/her mood after being exposed to the learning activity (Table 3.1)

SAMPLE SIZE

Since the idea was to invite all the students in each class chosen by the centre coordinator and aim to reproduce the "real world", in a pragamatic trial, we did not make any sample size calculations. Considering we have several centres included, we did not believe this aspect could compromise the power of statistical analysis considering the primary outcome chosen.

Table 3.1 - Multicenter IusTC's outcomes chart. The grey cells are signalizing outcomes explored in this chapter. (ITT: Intention-to-treat analysis and PP:Per-Protocol analysis)

	TIME OF ASSESSMENT	EXPECTED LEARNING OUTCOMES	ASSESSMENT METHODS	MEASURE UNIT	STATISTICAL ANALYSIS
Effectiveness of the teaching methods (Students' achievement)	**Short-term** (immediately after training activities)	Development of practical skills for detecting caries lesions *(primary outcome)*	Practical test - simulating the oral environment: Part A - to score pre-selected dental surfaces regarding severity Part B – to score the same surfaces according to caries activity status (those characteristics remaining in vitro)	Correct scored surfaces regarding severity (Unit: assessment) Correct scored surfaces regarding activity status (Unit: assessment)	Multilevel Poisson regression analysis (ITT) *(Dicothomous outcomes Yes vs. no -ref)*
		Acquisition of theoretical knowledge in caries detection	Theoretical test – to answer questions about caries detection	Overall achievement Grades from 0 to 10 (Unit: student)	Multilevel Poisson regression analysis (ITT) *(Count outcome)*
		Ability/Attitude for decision-making after performing caries detection, considering the possible choices	Evaluation of 5 clinical cases representing different conditions or contexts related to caries detection (severity/activity) and posterior clinical mangement	Correct answers for Detection Activity status Caries lesions management (Unit: assessment)	Multilevel Poisson regression analysis (ITT) *(Dicothomous outcomes Yes vs. no - ref)*
	Long-term (after students completing graduation)	Knowledge Retention	Theoretical test – to answer questions about caries detection involving knowledge by itself, ability to use such	Overall achievement Grades from 0 to 10 (Unit: student)	Multilevel Poisson regression analysis (ITT) *(Count outcome)*
		Practical skills	Practical test – to assess 3 clinical cases representing different conditions or contexts related to caries detection (severity/activity)	Correct answers for Detection Activity status Caries lesions management (Unit: assessment)	Multilevel Poisson regression analysis (ITT) *(Dicothomous outcomes Yes vs. no -ref)*
Student-Centred Outcomes	Immediately after training activities	Self-perceived student's confidence in his/her performance in practical test	Question: "Do you believe that you had a good performance in this practical test?	0: absolutely not to 5: very much (Unit: student)	Multilevel Poisson regression analysis (PP) *(Count outcome)*
		Importance of using an index for aiding caries detection	Question: "How important do you believe is using ICDAS for caries detection?"	VAS Scale 0 to 10 (Unit: student)	Multilevel Poisson regression analysis (PP) *(Count outcome)*
		Students' perception of his/her mood after the learning activity	Parts of the State Trait Personality Inventory scale "After the activity, are you: 1. Nervous? 2. Satisfied? 3. Bored?	Score registered in a 4-Likert Scale Categorizhed as: 0: No (absolutely not, little bit) 1: yes (moderately, very much) (Unit: student)	Multilevel Poisson regression analysis (PP) *(Dicothomous outcomes Yes vs. no -ref)*
Cost *(See Chapter 3)*	During the implementation and delivery phases of the teaching strategies	Estimation and valuing of the additional resources involved in delivering the alternative learning activity	Costs Micro-costing approach	Incremental cost International dollars (Units: Student/class)	Cost assessment (ITT) Budget Impact Analysis
Cost-effectiveness *(See chapter 4)*	Short-term effects Immediately after the activity	Estimation of the efficiency in using resources when using the alternative learning activity to substitute the traditional one	Costs Short-term effects above	Incremental cost Incremental effects (Units: Student/Centre)	Cost-effectiveness analysis (ITT) Sensitivity analysis per centre
	Long-term effects After long-term knowledge retention		Costs Long-term effects above		

Source: The Author

RANDOMIZATION

The randomization process was performed per included classroom. The unit of randomization was the student. In case a classroom will be divided due to limited space in the laboratory, each group of students to go to the lab simultaneously was considered a stratum and stratified randomization was performed.

A specific software generated the allocation sequence on the activity day. This step was performed by a member of the precursor coordinating centre. The concealment of the allocation was maintained until the beginning of the training activities. Until then, neither the researchers nor the students knew the group they were allocated to.

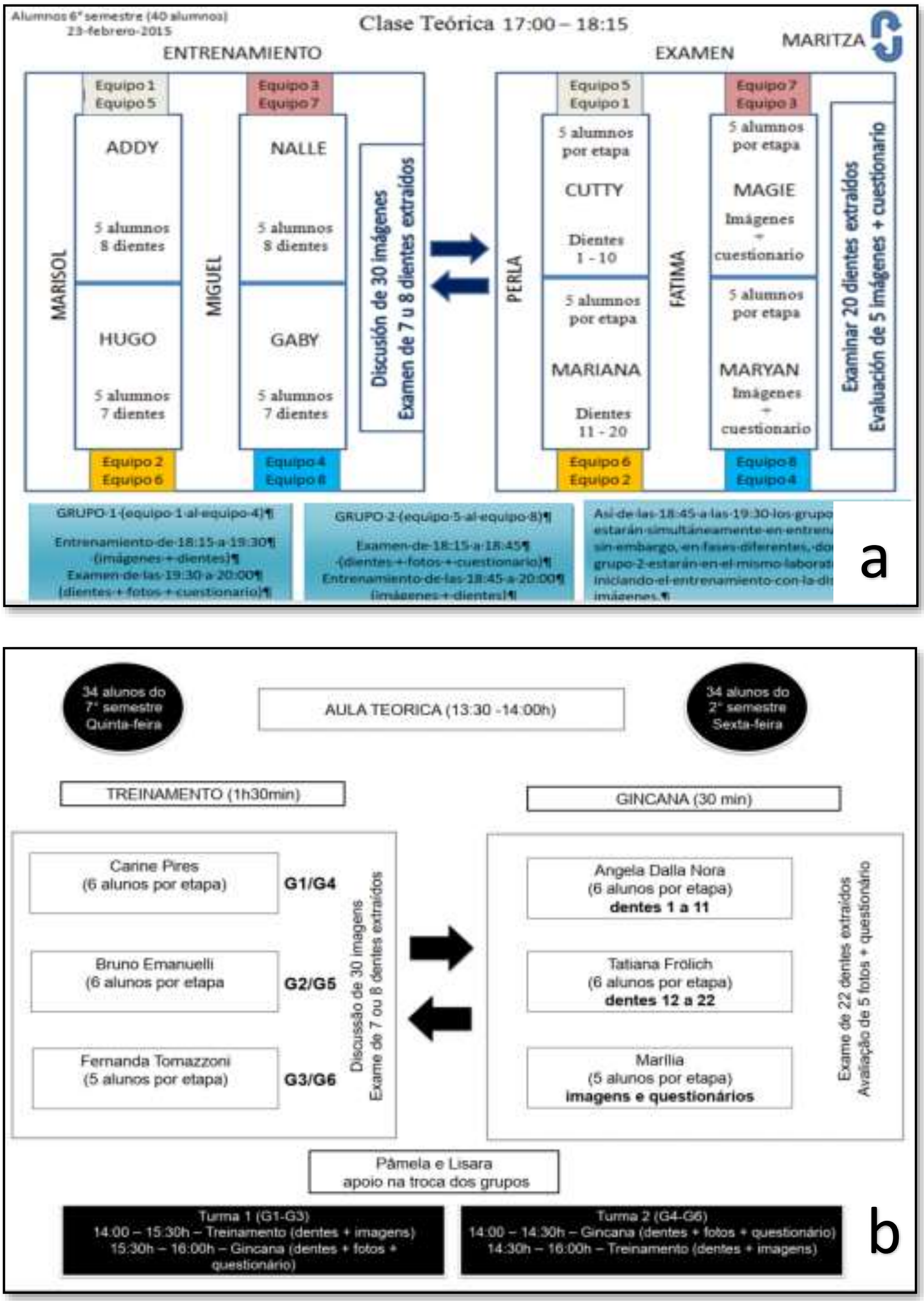
BLINDING

The groups in which students were divided received numbers (e.g. 1 to 8) and were not labelled test and control. After the lecture, students were directed to the laboratory. Half part of the groups (e.g. 1 to 4) began by performing the practical assessment. They were part of the control group. Other groups (e.g. 5 to 6) began with active learning training. As simultaneous activities did not present essentially the same format, we cannot guarantee the study was blinded entirely to the students. On the other hand, as activities happened simultaneously and the students were not aware of the content of each one, we suppose most of them did not notice which group they were allocated to (Figure 3.4 a, b).

STATISTICAL METHODS

All statistical analyses performed in this chapter aimed to identify if the proposed active-learning training activity impacted the primary and secondary outcomes explored. The unit of analysis was the assessment (dental surface or clinical case) or the student depending on the outcome under analysis (Table 3.1) Intention to treat analysis was considered for most outcomes, except for student-centred endpoints, for which we used per-protocol analysis for having the possibility of analyzing the missed answers separately. As the randomization was done using the complete list of students per class, but we could not identify the students, we could not input data for those students who were randomized but did not participate in the study. In case of missing data, when the outcomes were supposed to be classified into correct/incorrect answers, it was inputted as incorrect if a blank answer was found.

Figure 3.4 – Teaching activities happened simultaneously for the test and the control groups, according to the organization of the flow of participants in the laboratory



Source: The author.

We opted for using multilevel models for controlling the clustering effect that the centre may exert on the outcomes. This strategy is often used when exploring the educational context (26). Besides, this statistical approach also controls the student's clustering effect when the assessment (dental surface/clinical case) was the unit of analysis. The levels used were the assessment (when it was the case), the student and the centre. Then, the variance accounted for each level could be calculated and considered in the model results.

The classical use of Poisson regression was employed when count outcomes or variables presented a distribution that approximately fits the Poisson distribution had to be analyzed (27,28) (Table 3.1). Then, as estimates, we calculated the rate ratio (RR) with 95% of confidence interval (95% CI).

We also opted for using Poisson regression models with collected dichotomous data (Table 3.1). This option was an alternative to the logistic regression model. It has been used in the analysis of prospective studies with independent binary outcomes (28) as a manner to evaluate complex interactions with covariates (27) provides covariate-adjusted risk ratios and associated standard errors (28) and also provides a more reasonable interpretation than the odds ratio may provide (29). In these cases, we could estimate incidence rates with their 95% CI.

For each outcome, we first set the null model. Then, we build Model 1 only containing the intervention as the independent variable. Afterwards, Models 2, 3 and 4, adding progressively the relevant variables related to, respectively, the assessment, the student and the centre, were created. Independent variables collected were: centre (educational background, cariology curriculum, geographical location), student (formation level, self-reported confidence and preparedness) and assessment (lesion severity, type of surface).

Relevant assessment, student and centre variables were first tested in univariate analyses. Then, a level of 0.20 in the unadjusted analyses was regarded for variables entered into the model. A 0.05 significance level was set to variables being retained in the model. Other variables considered necessary for model adjustment were eventually maintained in the model irrespective of their statistical significance.

Subgroup analyses were performed considering different clinical conditions or theoretical concepts explored in the different outcome assessments.

3.3 RESULTS

CENTRE AND PARTICIPANT FLOW/ RECRUITMENT

The flow of study centres and participants is reported in Figure 3.5. From the 16 new educational institutions expected, we finally included 10 universities from different countries to participate in this multicentre study (besides the coordinating Brazilian center). A total of eleven dental schools were contemplated for the analysis. Reasons for the non-inclusion of centres are displayed in Figure 3.5. Recruitment was performed from 2009 to 2020 in the involved centers (see Chapter I).

1190 undergraduate dental students from 31 different classes in these centres were enrolled in the IuSTC01 trial. The response rate per centre is reported in Table 3.1. The mean response rate was 91.1% (SD=7.9%). Reasons for the non-inclusion of students could not be assessed since the forms were anonymously returned; we could not assess if the non-responses were due to the student's absence in the activity or disagreement in participating in the study.

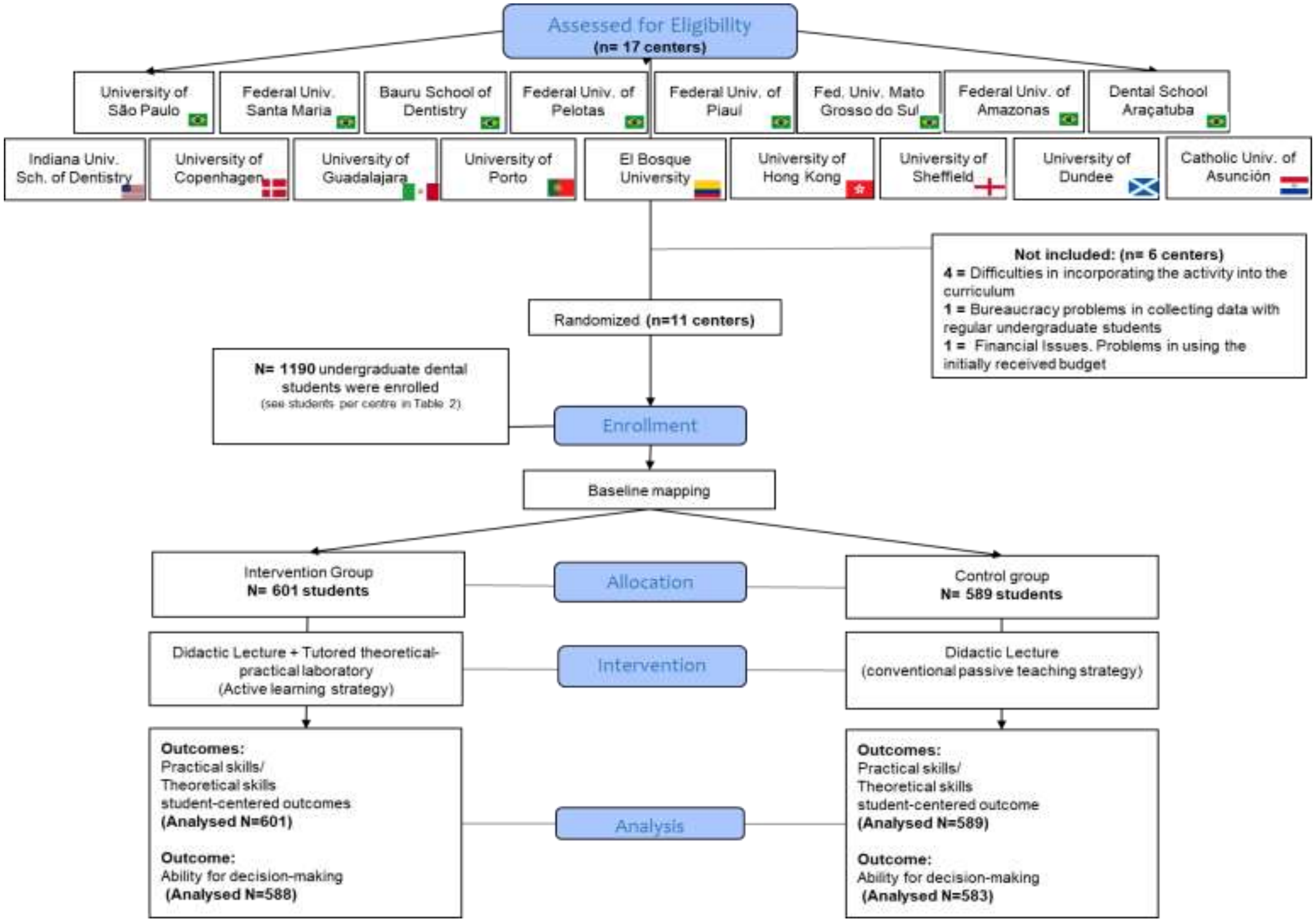
Baseline data

Of included students, 57% (n=684) were the first-years (without clinical experience), and 43% (n=506) were the last-years students. Once included, participants were similarly divided into two groups (49.5% - no training; 50.5% training). The average allocation rate was 0.98 (SD=0.01). Allocation rates for lecture and lecture+active-learning training varied from 0.84 to 1.05 depending on the centre (Table 3.2).

MAIN FINDINGS AND ESTIMATES

All the 1190 included undergraduate students were analyzed for the primary outcome and for the secondary outcomes related to learning effects. For the student-centre outcomes, as we use the per-protocol analyses, the number of analyzed students per outcome is reported in Figure 3.5.

Figure 3.5. - Flowchart of the multicenter controlled randomized trial, based on consort reporting.



Source: The Author

Table 3.2 – Baseline characteristics of the sample.

ID	Educational Institution	Location	Code	Classes Invited	Response Rate	Included students	Teaching Method	Allocation	Allocation Rate
1	University of São Paulo	São Paulo, Brazil	**USPSP**	7	97%	361	Only Lecture	174	0.93
							Lecture + Training	187	
2	Federal University of Santa Maria	Santa Maria, Brazil	**UFSMA**	4	90%	112	Only Lecture	56	1.00
							Lecture + Training	56	
3	School of Dentistry, University of São Paulo	Bauru, Brazil	**USPBA**	2	89%	89	Only Lecture	45	1.05
							Lecture + Training	43	
4	Federal University of Pelotas	Pelotas, Brazil	**UFPEL**	1	74%	49	Only Lecture	23	0.88
							Lecture + Training	26	
5	Federal University of Piauí	Piauí, Brazil	**UFPI**	6	91%	119	Only Lecture	59	0.98
							Lecture + Training	60	
6	Federal University of Mato Grosso do Sul	Campo Grande, Brazil	**UFMS**	2	88%	35	Only Lecture	16	0.84
							Lecture + Training	19	
7	University of Guadalajara,	Jalisco, Mexico	**UGUA**	1	100%	38	Only Lecture	19	1.00
							Lecture + Training	19	
8	University of Copenhagen	Copenhagen Denmark	**UCOPE**	3	89%	70	Only Lecture	33	0.89
							Lecture + Training	37	
9	University of Porto	Porto, Portugal	**UPORT**	2	87%	137	Only Lecture	73	1.14
							Lecture + Training	64	
10	El Bosque University,	Bogotá, Colombia	**UELBO**	2	96%	76	Only Lecture	38	1.00
							Lecture + Training	38	
11	Indiana University School of Dentistry	Indianapolis, United States	**IUSD**	1	100%	105	Only Lecture	53	1.02
							Lecture + Training	52	

Source: The author.

Students' Practical Skills

The theoretical-practical training adjoined to the lecture contributed positively to a higher occurrence of correct answers in the practical assessments with extracted teeth (Table 3.3). On average, actively-trained students (test group) improved approximately 7% of their practical ability (correct answers) in scoring the surfaces regarding caries severity (Table 3.4 – Model 1). Such result was slightly affected by other independent variables tested as the level of students' training (first-years vs last-years) or even the educational institutions' patterns (previous use of ICDAS or not) (Table 3.4 – Models 2 to 4).

Table 3.3 – Proportion of correct answers for practical assessment in both groups.

TEACHING METHOD	**SEVERITY DETECTION**		**ACTIVITY STATUS**	
	Correct Answers % (95%CI)	Incorrect Answers % (95%CI)	Correct Answers % (95%CI)	Wrong Answers % (95%CI)
Only Lecture (passive learning)	**55%** (47-62%)	**45%** (38-53%)	**44%** (40-47%)	**56%** (53-60%)
Lecture + Training (active learning)	**60%** (54-66%)	**40%** (35-46%)	**59%** (56-63%)	**41%** (37-44%)

Source: The Author

All models showed a higher variance for the centre level than for the student level (Table 3.4). Model 2, including the intervention and covariates adjustment for dental clinical condition (caries severity), presented the lowest variance for both centre and student levels (Table 3.4). In this model, we could demonstrate students scored more correctly on the initial (around 20%) and severe caries lesions (around 40%) than on sound surfaces (Table 3.4-Model 2).

Table 3.4. - Poisson regression analysis for student's practical skills for detecting caries lesion and scoring its severity (IRR= Incidence rate ratios, 95%CI: confidence intervals)

Null Model:	Univariate Models		Model 1 (Intervention variable)		Model 2 (Intervention variable + Assessment variables)		Model 3 Intervention variable + Assessment + Student variables		Model 4 Intervention variable + Assessment + Student + Centre variables	
Independent Variables	**IRR (95% CI)**	**P value**	**Robust IRR (95% CI)**	**P value**	**Robust IRR (95% CI)**	**P value**	**Robust IRR (95% CI)**	**P value**	**Robust IRR (95% CI)**	45
Laboratorial tutored training (ref. No)	-	-								
Yes	-	-	1.07 (1.02 to 1.11)	0.003	1.09 (1.04 to 1.14)	<0.001	1.09 (1.04 to 1.14)	<0.001	1.07 (1.03 to 1.12)	<0.001
Caries lesions severity (ref. sound teeth)										
Initial Lesions (ICDAS 1-2)	1.20 (1.11 to 1.30)	<0.001			1.23 (1.14 to 1.32)	<0.001	1.20 (1.11 to 1.29)	<0.001	1.19 (1.10 to 1.28)	<0.001
Moderate Lesions (ICDAS 3-4)	0.98 (0.84 to 1.13)	0.744			0.99 (0.85 to 1.17)	0.950	0.97 (0.84 to 1.13)	0.711	0.97 (0.83 to 1.12)	0.639
Severe Lesions (ICDAS 5-6)	1.39 (1.27 to 1.53)	<0.001			1.42 (1.30 to 1.55)	<0.001	1.39 (1.26 to 1.53)	<0.001	1.38 (1.26 to 1.52)	<0.001
Students' level of training (ref. first-years)										
Last-years	1.07 (0.98 to 1016)	0.141					1.05 (0.98 to 1.14)	0.182	1.06 (0.99 to 1.13)	0.094
Previous use of ICDAS (ref. No)										
Yes	1.15 (1.00 to 1.32)	0.045							1.10 (0.97 to 1.14)	0.150
Theoretical performance	1.00 (0.99 to1.02)	0.74								
Center Level Variance			170875.4		2.259192		210306.8		65381705	
Student Level Variance			691.1333		0.4683115		0.4502152		259.9581	

Source: Author

When assessing the caries activity status, these improvements on practical skills were still more evident. A 36%-increase in the students' correct answers was found among students who received the additional active-learning training compared to those who had not participated in such a learning activity (Table 3.5). Active lesions were 25% more correctly assessed than sound surfaces when including the activity status in the model (Table 3.5 - Model 2). However, no differences in correct answers were observed between inactive vs active caries lesions (IRR= 0.87; 95%CI=0.71 to 1.06). A narrower range of variances was observed among the Models tested for activity. In all of them, the student level explained most of it (Table 3.5).

When different clinical conditions were considered in the subgroup analyses, we could explore different effects of the intervention in each (Table 3.6). On average, almost 20% more correct answers were observed in the trained group among sound surfaces scored. This increasing rate was approximately 10% for initial and severe caries lesions (Table 3.6). Correct lesions on moderate lesions tended to be higher when students were trained, but this difference was not statistically significant (Table 3.6). The differential effect of the intervention under different activity statuses. On average, active areas and sound surfaces had 50% and 20% more correct answers when students had been actively-trained compared to those who only attended the lecture (Table 3.6).

Table 3.5. – Poisson regression analysis for student’s practical skills for assessing caries lesion activity (IRR= Incidence rate ratios, 95%CI: confidence intervals)

Null Model: 1.36 (1.24 to 1.49) P value = <0.001	**Univariate Models**		**Model 1 (Intervention variable)**		**Model 2 (Intervention variable + Assessment variables)**		**Model 3 (Intervention variable + Assessment + Student variables)**	
Independent Variables	**IRR (95% CI)**	**P value**	**Robust IRR (95% CI)**	**P value**	**Robust IRR (95% CI)**	**P value**	**Robust IRR (95% CI)**	**P value**
Laboratorial tutored training (ref. No)								
Yes	-	-	1.36 (1.24 to 1.47)	<0.001	1.36 (1.24 to 1.48)	<0.001	1.36 (1.24 to 1.49)	<0.001
Caries lesions severity (ref. sound teeth)								
Initial Lesions (ICDAS 1-2)	1.00 (0.78 to 1.29)	0.99						
Moderate Lesions (ICDAS 3-4)	1.16 (0.95 to 1.41)	0.137						
Severe Lesions (ICDAS 5-6)	1.41 (1.15 to 1.71)	0.001						
Activity status of caries lesions (ref. no activity)								
Inactive	0.87 (0.71 to 1.07)	0.181			0.87 (0.70 to 1.08)	0.204	0.87 (0.71 to 1.07)	0.178
Active	1.24 (1.01 to 1.52)	0.039			1.24 (1.01 to 1.52)	0.038	1.24 (1.01 to 1.52)	0.039
Students’ level of training (ref. first-years)								
Last-years	1.06 (1.01 to 1.10)	0.007						
Previous use of ICDAS (ref. No)								
Yes	1.06 (1.03 to 1.10)	0.001						
Theoretical performance	0.99 (0.99 to 1.01)	0.523						
Center (constant variable)			1.75e+07		1.51e+07		1.79e+07	
Student (constant variable)			2.45e+07		2.48e+07		2.39e+07	

Source: Author

Table 3.6 - Subgroup analysis associating the correct answers in the practical assessments with different clinical conditions (caries lesions severity and activity status - IRR= Incidence rate ratios, 95%CI: confidence intervals)

CARIES LESIONS SEVERITY				
	Only Lecture Correct answers % (95% CI)	Lecture+Training Correct answers % (95% CI)	Adjusted IRR	P value
Sound Surfaces	**46%** (37–55%)	**52%** (42–62%)	**1.19** (1.01 to 1.14)	0.036
Initial Lesions (ICDAS 1-2)	**59%** (50–66%)	**63%** (54–70%)	**1.08** (1.02 to 1.14)	0.007
Moderate Lesions (ICDAS 3-4)	**46%** (41–51%)	**50%** (41–59%)	**1.05** (0.88 to 1.26)	0.557
Severe Lesions (ICDAS 5-6)	**65%** (52–76%)	**72%** (57–83%)	**1.09** (1.04 to 1.14)	<0.001
LESIONS` ACTIVITY STATUS				
	Only Lecture Correct answers % (95% CI)	Lecture+Training Correct answers % (95% CI)	Adjusted IRR	P value
Sound areas	**41%** (30–52%)	**49%** (37–61%)	**1.20** (1.01 to 1.43)	0.034
Inactive areas	**42%** (38–46%)	**38%** (32–44%)	**0.90** (0.74 to 1.09)	0.283
Active areas	**45%** (40–49%)	**66%** (62–70%)	**1.50** (1.33 to 1.67)	<0.001

Source: The author.

Theoretical skills

The overall mean score for trained and not trained students were 7.98 and 7.88, respectively. The active-learning training on caries detection did not affect students' theoretical knowledge about such a concept and its application (RR=1.01; 95%CI: 0.97 to 1.06) (Table 3.7). Individual findings per question are presented in Table 3.6. The lowest correctness rates were observed for questions that assessed students' attitudes toward using the knowledge, and the new proposed activity learning did not impact this outcome (Table 3.7). A specific contribution in theoretical skills was observed in knowledge about initial lesions (Table 3.7– blue cells).

Ability/Attitude for decision-making after performing caries detection

Both groups presented a similar and high percentage (higher than 80%) of correct answers on scoring caries lesion severity (Table 3.8). The active-learning strategy, however, positively impacted the assessment of the presented cases' caries lesions activity status. On average, the actively trained group observed 10% more correct answers on students' activity assessments (Tables 3.8 and 3.9). Finally, for managing the dental surfaces scores, poor students' performance was observed (only around 20% of correct answers) (Table 3.9 and 3.10) and was not impacted by the learning strategy used (Table 3.10). A higher percentage of missing responses, particularly in this subject, were registered by the passive-learning group (53%) compared to active-learning (47%). In different models, the centre level was associated with higher variance than the student one.

Table 3.7. – Theoretical assessment findings detailed by different contents and types of assessments (knowledge, ability or attitude). Blue cells highlighted

Question	Q1	Q2	Q3	Q4a	Q4b
Type of question	Critical question (multiple choice)	Inference question (multiple choice)	Problem-solving question (multiple choice)	Open question	Open question
Clinical condition	Initial lesions	Initial lesions	Moderate lesions	Initial lesions	Moderate lesions
Content	Awareness about visual index for caries detection	Impact of false diagnosis	Awareness about visual index for caries detection	Impact of false diagnosis related to moderate lesions (critical threshold)	
Question	*ICDAS scores 1 and 2 characterize the detection of enamel opacities. Select the correct answer:*	*Select the correct answer concerning the detection and management of caries lesions:*	*A 6-year-old female patient presents a micro-cavity (affecting enamel only) on the occlusal surface of her maxillary right second molar. After professional prophylaxis and surface drying, you detect the presence of an underlying grey shadow associated with the previously detected micro-cavity*	*What would be the clinical consequence if a caries lesion is wrongly scored in the following situations: Scoring ICDAS 2 when is a lesion ICDAS 1*	*What would be the clinical consequence if a caries lesion is wrongly scored in the following situations: Scoring ICDAS 3 when is a lesion ICDAS 4*
Answer Key	*ICDAS score 2 characterizes the detection of opacities seen even in the presence of humidity*	*The early detection of initial lesions (ICDAS 1 and 2) is essential for adopting preventive measures favouring a better prognosis in controlling their progression.*	*The lesion classification according to ICDAS is score 4, characterized by an underlying grey shadow.*	*No consequence because they have the same progression estimate, and they would receive the same management*	*The consequence of underestimating the lesion. Score 4 has a faster progression because it is in dentin*
Type of Assessment*	Knowledge	Ability	Knowledge	Attitude	Attitude
CONTROL GROUP % of correct answers	**0.87**	**0.91**	**0.84**	**0.63**	**0.71**
TEST GROUP % of correct answers	**0.91**	**0.84**	**0.86**	**0.68**	**0.74**
RR(95%CI)	**1.05 (1.01 to 1.08)**	**0.92 (0.86 to 0.98)**	**1.02 (0.98 to 1.06)**	**1.07 (0.97 to 1.19)**	**1.05 (0.95 to 1.15)**

Source: The Author

Table 3.8. – Correct answers given by students when ability/attitude in clinical decision-making was assessed presenting simulated clinical cases.

Learning Objective	**CASE 1**		**CASE 2**		**CASE 3**		**CASE 4**		**CASE 5**	
Identify presence of caries lesions, score their severity and activity status, and decide about their management	**BUCCAL SURFACE** 		**MESIAL SURFACE** 		**BUCCAL SURFACE** 		**OCLUSSAL SURFACE** 		**OCLUSSAL SURFACE** 	
Type of Assessment: ***Scoring severity*** **ABILITY**	ICDAS score: 4 **MODERATE**		ICDAS score: 2 **INITIAL**		ICDAS score: 2 **INITIAL**		ICDAS score:6 **EXTENSIVE**		ICDAS score:3 **MODERATE**	
Activity status assessment **ABILITY**	Activity status: **ACTIVE**		Activity status: **ACTIVE**		Activity status: **ACTIVE**		Activity status: **ACTIVE**		Activity status: **INACTIVE**	
Clinical decision-making about management ATTITUDE	Management: **NON-OPERATIVE**		Management: **NON-OPERATIVE**		Management: **NON-OPERATIVE**		Management: **OPERATIVE**		Management: **NON-OPERATIVE**	
Proportions of correct answers for:	**Control group**	**Test group**	**Control group**	**Test group**	**Control group**	**Test group**	**Control group**	**Test group**	**Control group**	**Test group**
DETECTION	86% (82-89%)	82% (78-85%)	87% (76-93%)	80% (71-87%)	84% (76-90%)	83% (79-86%)	87% (82-91%)	82% (77-87%)	85% (81-89%)	83% (79-87%)
ACTIVITY	57% (52-62%)	62% (56-66%)	56% (50-62%)	63% (56-69%)	56% (49-62%)	63% (58-68%)	58% (55-60%)	61% (55-67%)	64% (51-67%)	65% (59-69%)

Source: Author

Table 3.9. – Poisson Regression Analysis for student's ability/attitudes in clinical decision-making when scoring caries lesion severity, assessing caries lesion activity status and decision caries management (IRR= Incidence rate ratios, 95%CI: confidence intervals)

Independent Variables	SEVERITY				ACTIVITY				MANAGEMENT			
	Univariate Models		Model 1		Univariate Models		Model 1		Univariate Models		Model 1	
	IRR (95% CI)	P value	Robust IRR (95% CI)	P value	IRR (95% CI)	P value	Robust IRR (95% CI)	P value	IRR (95% CI)	P value	Robust IRR (95% CI)	P value
Laboratorial training (ref. No)												
Yes	0.96 (0.89 to 1.03)	0.215	0.96 (0.89 to 1.02)	0.215	1.10 (1.02 to 1.18)	<0.001	1.10 (1.02 to 1.18)	0.008	0.96 (0.86 to 1.07)	0.43	0.96 (0.86 to 1.07)	0.43
Caries lesions severity (ref. initial lesions)												
Moderate Lesions (ICDAS 3-4)	0.79 (0.73 to 0.84)	<0.001	0.79 (0.73 to 0.84)	<0.001	0.66 (0.59 to 0.73)	<0.001	0.66 (0.59 to 0.73)	<0.001	7.99 (0.97 to 66.06)	0.054		
Severe Lesions (ICDAS 5-6)	1.09 (1.08 to 1.11)		1.09 (1.08 to 1.11)	<0.001	1.24 (1.13 to 1.35)	<0.001	1.24 (1.13 to 1.35)	<0.001	26.65 (3.61 to 196.58)			
Students' level of training (ref. first-years)									0.98 (0.92 to 1.03)	0.397	0.98 (0.92 to 1.03)	0.397
Last-years					0.99 (0.92 to 1.06)	0.757	0.99 (0.92 to 1.06)	0.690				
Management (ref. non-operative)												
Operative treatment											34.06 (4.62 to 251.215.15)	0.001
No treatment											19.97 (2.30 to 172.94)	0.007
Center (constant var.)			3.38e-34				0.0025687				0.703997	
Student (constant var.)			5.17e-35				7.67e-38				5.16e-07	

Source: Author

Table 3.10 - Proportion of correct answers for in both groups in assessing the severity, activity and management of simulated clinical cases

	SEVERITY DETECTION		ACTIVITY STATUS		MANAGEMENT	
TEACHING METHOD	**Only Lecture**	**Lecture + Training**	**Only Lecture**	**Lecture + Training**	**Only Lecture**	**Lecture + Training**
Incorrect Answers % (95%CI)	**14%**	**18%**	**43%**	**37%**	**71%**	**72%**
Correct Answers % (95%CI)	**86%**	**82%**	**57%**	**63%**	**29%**	**28%**

Source: The Author

Student-centred outcomes

Students who participated in the active learning perceived their performance (preparation) for detecting caries lesions in the practical assessment more positively than those who only attended the didactical lecture (trained: Mean=1.78; 95%CI: 1.63 to 1.93), non-trained: Mean=1.55; 95%CI: 1.31 to 1.80). They also reported a higher level of importance for using an index for caries detection (Mean=8.93; 95%CI:8.49 to 9.38) than those who had not participate in this training (Mean=8.80; 95%CI:8.36 to 9.25).

A relative difference of approximately 15% was found regarding students' satisfaction after learning activities in favor of the trained group (trained: 74% non-trained: 26%, RR=1.16; 95%CI: 1.07 to 1.27). No significant differences were found when other feelings were assessed after learning activities (bored- RR=1.32; 95%CI: 0.86 to 2.01/ nervous -RR=0.88; 95%CI: 0.75 to 1.03).

ADVERSE EVENTS/HARMS

No adverse events or harms were reported during the study. No incidents and complaints were registered by moderators when monitoring study implementation.

3.4 DISCUSSION

This study, designed to test in a real-world educational context, if a new active-learning teaching strategy involving tutored theoretical-practical training brings relevant highlights regarding the educational effects and learners' changes such kind of learning strategy offers. Indeed, the main contribution expected and confirmed was the development of practical skills in caries detection. By engaging in this teaching methodology, students that received laboratory training had the opportunity to simulate, in a preclinical "safe environment", a sequence of actions that would be necessary to be accomplished in a real clinical examination, but not under the pressure of working with patients may cause. Furthermore, using the proposed learning strategy, a wider diversity of clinical situations could be simulated, which would not have been feasible in a clinical setting, seeing patients individually. Therefore, students may have been able to anticipate some difficulties that they might have in the future and learn from them, becoming more confident and proficient in caries detection.

Preclinical activities have established importance in dental education. Nevertheless, most studies have focused on preparing students technically and not stimulating their critical thinking skills (30). This aspect is undoubtedly a strength and a differential of the proposed learning strategy. We progressively constructed with students the rationale of their use to decide how to assess and score caries lesions. In these successive attempts, the acquired knowledge is applied in an actual situation, not randomly, but intentionally and in a guided way to explore essential aspects of that process. Gains in students' practical skills to assess activity status reinforces such a premise. Even by creating a simulation to didactically train the process (since activity status does not make sense outside the oral environment (31), students could eminently practice the concepts and align them to their clinical assessment and decision-making abilities. Indeed, to improve the learning of a skill, practicing in varied situations and with different difficulties is required (32). Furthermore, a good approximation of the clinical practice through this simulation was probably achieved, and discussions generated in small groups may have been responsible for such findings.

The practical skills development more evidently demonstrated in actively trained students was the proxy endpoint we expect to achieve to produce a future dentist able to make an appropriate clinical decision related to caries lesions. This aspect is another relevant advantage of our study; the primary endpoint was chosen to measure the educational effect of the learning activity. Few studies have explored caries detection methods for training students (33–35). However, almost all of them were mainly devised for a particular or partial group of students. They did not present a control group or comparators to contrast with the tested methodology (34,36–38). Commonly, educational researchers do not evaluate the impact of teaching activities on students' practical skills, only students' perceptions (39) or the reproducibility of the teaching method (40). These are also important outcomes but they do not guarantee the activity proposed will reach the expected achievements in the real world. Then, they are not sufficient to endorse the implementation of such learning on an extensive basis.

The level of students' experience has been shown to have an influence on caries detection, sometimes associating less experienced examiners to false positive results (38,41–43). However, the effect of the active-learning intervention on educational outcomes was rarely influenced by that. We hypothesized that any influence of previous clinical experience acquired should have been minimized by the effect of the training received. This strategy is a satisfactory manner to unify and balance students' abilities, even considering different backgrounds.

The benefit of using this strategy exists. Then, the other question is the relevance of this benefit achieved. One can argue that a 10%-difference, as observed for caries lesion severity scoring, may not be an expressive value. Despite the magnitude per se, let's reflect on specific types of repercussions such change may result in. Subgroup analyses permitted such exploration. Firstly, the benefits of training students to reduce false positive results for sound surfaces and the reduction of false negative results for extensive caries lesions should be emphasized. Long-term consequences of false-positive cannot be assumed to be equal to false-negative diagnoses (44,45). Preventing false positive results is a general concern associated with caries detection since unnecessary treatment will lead to overtreatment. It is essential to interpret findings correctly, to minimize financial and human costs associated with incorrect diagnosis (46). Differentiating if there is (or not) a caries lesion to be scheduled for operative intervention may represent an even significant impact (47).

Based on that, the impact of this teaching activity for training on caries detection should also be understood as we judge diagnosis tests' performance. Clear examples of unnecessary waste of resources are when we treat unnecessarily sound surfaces. Neglecting to detect and consequently treat severe caries lesions is also relevant to be avoided. These lesions are usually more prone to progressing and complicating to more complex situations, more difficult and costly to manage, and causing painful patient experiences (48).

Recognizing appropriately active lesions was also a contribution of implementing active training focused on developing this challenge. Since caries lesion activity status reflects a dynamic process (49), activity assessment was not a primary ability to develop with students in clinical photographs or extracted teeth. However, we opted to work on characteristics related to these different activity statuses (31) in workgroups to avoid leaving this step behind when assessing caries lesions. Identifying the active lesions is also a direct treatment method and often avoids overtreatment. This unexpected contribution from the learning activity highlighted the importance of maintaining this original format of the theoretical-practical activity in which students conjointly score the severity and assess the activity status of caries lesions

Although beneficial findings are derived from the educational intervention, we must also stress out some aspects that deserve modifications to produce better results in further deliveries of an activity like that. The most critical point is the detection of moderate lesions. Moderate lesions are not such prevalent lesions (around 10% of surfaces presented one of them (50). On the other hand, its progression is faster than initial lesions, and approximately 50% of these lesions progressed in 2 years (51). We empirically recognize that detecting this kind of caries lesion is a big deal for students. Similar patterns have already been observed elsewhere (46). Therefore, instructors should give special attention to those lesions deserve, and additional strategies should be created and tested to minimize such gaps and minimize the persistent difficulty of diagnosis observed by students and clinicians at this threshold.

Other educational effects did not express any additional benefit of the learning activity proposed. Some points should be raised regarding these findings. Firstly, improvement of already good outcomes is challenging. We have a mathematical problem of increasing a percentage already close to 90%, as was the case of theoretical and some decision-making assessments. Additionally, health professions tend to resist change on something that already appears to deliver good results (52). On the other hand, since many of these competencies could be developed even only by attending the lecture, we do not believe it could be a disadvantage.

A real gap left by the learning strategy was identified when an assessed competence is not considered a good outcome but could not be improved during the learning process. Clinical decision-making was not the primary aim when the learning strategy was devised. We indirectly expected that we would enhance clinical decision-making on managing such detected lesions when improving students' practical skills for caries detection and activity assessment. Nevertheless, this framework was not so linear. Our findings suggested even by scoring the lesions effectively and improving practical skills for assessing caries activity; many students made a correct diagnosis. Still, the minority (no more than 30%) opted for the more appropriate management. A possible reason for that is the intrinsically operative paradigm still embedded in some dental schools/lecturers that can influence on students' threshold to opt for restoring instead of controlling caries lesions (53). Besides, we speculate students in simulated clinical situations may first decide on the treatment as an arc reflex without rationalizing the diagnosis. This hypothesis might explain why both parts seem not to make sense together.

These findings make us reflect that we still need to work better with students to link these two competencies (diagnosis and management) and stimulate reflective practice. Therefore, students can rationalize the diagnosis of caries lesions profoundly and do not neglect therapeutic decisions (48,49). The non-development of reflective practice skills among dental undergraduate students may eventually cause difficulties in clinical practice and would also reinforce the philosophy of operative care, which we tried to limit nowadays (2). Opportunely, the importance of reflective practice is recently getting more and more attention from educators, especially in health professionals' education. Still, it needs to be better explored for dental teaching and clinical learning activities (50).

The robustness of the findings presented until this stage are highly related to the diligence in designing and conducting this multicentre educational trial. We could investigate preclinical activities as an interventional strategy for multiple centres or in different dental schools' contexts. Multicenter research has several benefits over single-center studies (54), because it permits to have larger samples, increase the generalizability of the results, and enhance the collaboration among the centers, allowing even to share some resources and to work in very diverse scenarios at the same time (55). The included institutions represented different regions in America and Europe and brought some valuable contributions with their backgrounds and particularities to this study. Therefore, the intervention could be adapted for different realities and was proved to present a great educational value, that could be generalized practically worldwide. We cannot strictly affirm as really worldwide since African and Oceania centres could not be included, which is a study limitation we have to state at this point.

Centres' variety of different outcomes could not be hidden. Besides, different sample sizes for each centre were included since we approximate this pragramtic trial of a real attempt for implementing a new educational strategy. Appropriate statistical approaches were used, however, to lead with this questions. The multilevel regression models permit the adjustment for these differential characteristics and estimate the variance accounted for them (56).

The findings of this multicenter study brought up the importance that teaching methods play for the effective education of dental students. The impact of tutored activities, together with a range of other active learning resources such collaborative learning in small-groups discussions, laboratorial simulation training with extracted teeth, and immediate feedback from tutors about clinical cases, were crucial to promote a positive learning experience to students and to improve the achievement of some set learning outcomes. In fact, a high level of variance was observed for the centre level in different multilevel models analyzed. Centres variability is comprehensible. They represent different cultural, geographical, and curricular characteristics that we intentionally created as designing the present multicentre trial. Each particularity should be seen carefully given such variations. However, the gain in the power of generalizing the results of this pragamatic attempt in the educational field may compensate these eventual challenges.

Performing a research protocol in an educational field is not an easy task, particularly considering the magnitude of this study. Still, the design of the whole training activity tested here was aligned with the concept of reflective teaching. It was mainly focused on educating academically trained dentists with profound knowledge about preventing, diagnosing, treating, and controlling oral diseases (45) instead of just interventionist dentists (2). We observed that they improved their overall practical abilities and were allowed to applicate their knowledge, interacting with peers and tutors during the activities, revealing relative flexibility of the teaching method to the different learning styles of students (57,58).

We consider that exposing dental students to different activities and conditions related to caries disease process was a valid alternative to explore their reasonability of leading with different situations that could influence clinical decision-making. This approach has been used in different fields (59,60) to prepare the students for potential professional situations they could encounter in the future. Active learning resources that were used in this study and activities with extracted teeth contributed to simulating exam condition, however, it is not identical, but it is closer to clinical conditions compared to images. In addition, students may experience the need of using illumination, drying, and gently probing as in the case of a clinical setting. The opportunity of feeling the enamel and dentine textures, as their optical properties, is also an advantage of using this strategy. Despite not being the perfect method for training, the use of images associated with extracted teeth in such preclinical activities should be considered an alternative for training undergraduate students.

In conclusion, the theoretical-pratical preclinical training impacts positively the students' practical skills on caries detection, besides it also benefits the student-centred outcomes related to their performances. Further studies should be conducted to assess the impact of such training strategies during undergraduate courses and in further clinical practice. Besides, other outcomes like the cost-effectiveness should be investigated.

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ANNEX A - GREET checklist*

	page
Item 1 INTERVENTION: Provide a brief description of the educational intervention for all groups involved [e.g. control and comparator(s)].	**1**
Item 2 THEORY: Describe the educational theory (ies), concept or approach used in the intervention.	**57**
Item 3 LEARNING OBJECTIVES: Describe the learning objectives for all groups involved in the educational intervention.	**58**
Item 4 EBP CONTENT: List the foundation steps of EBP (ask, acquire, appraise, apply, assess) incluc in the educational intervention.	**58**
Item 5 MATERIALS: Describe the specific educational materials used in the educational intervention. Include materials provided to the learners and those used in the training of educational intervention providers.	**8**
Item 6 EDUCATIONAL STRATEGIES: Describe the teaching / learning strategies (e.g. tutorials, lectures, online modules) used in the educational intervention.	**58**
Item 7 INCENTIVES: Describe any incentives or reimbursements provided to the learners.	**9**
Item 8 INSTRUCTORS: For each instructor(s) involved in the educational intervention describe their professional discipline, teaching experience / expertise. Include any specific training related to the educational intervention provided for the instructor(s).	**10**
Item 9 DELIVERY: Describe the modes of delivery (e.g. face-to-face, internet or independent study package) of the educational intervention. Include whether the intervention was provided individually or in a group and the ratio of learners to instructors.	**11**
Item 10 ENVIRONMENT: Describe the relevant physical learning spaces (e.g. conference, university lecture theatre, hospital ward, community) where the teaching / learning occurred.	**12**
Item 11 SCHEDULE: Describe the scheduling of the educational intervention including the number of sessions, their frequency, timing and duration.	**12**
Item 12 Describe the amount of time learners spent in face to face contact with instructors and any designated time spent in self-directed learning activities.	**14**
Item 13 Did the educational intervention require specific adaptation for the learners? If yes, please describe the adaptations made for the learner(s) or group(s).	**14**
Item 14 Was the educational intervention modified **during** the course of the study? If yes, describe the changes (what, why, when, and how).	**15**
Item 15 ATTENDANCE: Describe the learner attendance, including how this was assessed and by whom. Describe any strategies that were used to facilitate attendance	**15**
Item 16 Describe any processes used to determine whether the materials (item 5) and the educational strategies (item 6) used in the educational intervention were delivered as originally planned**.**	**16**
Item 17 Describe the extent to which the number of sessions, their frequency, timing and duration for the educational intervention was delivered as scheduled (item 11).	**17**

4 CHAPTER III: WHERE DO WE PUT THE MONEY FOR IMPLEMENTING ACTIVE LEARNING ON CARIES DETECTION? – AN EDUCATIONAL TRIAL-BASED ECONOMIC EVALUATION

ABSTRACT

This trial-based economic evaluation aimed to estimate the incremental cost of implementing a theoretical-practical workshop for undergraduate students' training in caries detection to substitute the theoretical activity solely. We also provided a budget impact analysis and explored the final cost composition related to the teaching activity. For this evaluation, data from the coordinator centre of a randomized and controlled multicentre study (IuSTC01) was gathered. The perspective of the educational provider (university) was considered for the analysis of implementing the new activity and an immediate time horizon was adopted. The resources spent in the teaching activities were recorded and then valued using a micro costing strategy. After that, they were converted into international dollars. The incremental cost per student and the total cost for implementing the complete strategy for 80 students (organizational budget impact) were calculated. Monte Carlo simulations were used to estimate the uncertainties. The incremental cost for the workshop implementation would be $7.96 per student (interquartile interval-IQI: $6.7-7.2). The total cost of the complete educational activity would be approximately $684 (IQI:587–621) for a group of 80 students. Students' laboratory training comprised more than 50% of the total cost. A higher percentage of this value was related to human resources costs (72%). Saving up to 40% could be expected for the next rounds of activities, assuming no need for additional preparation of didactic material and tutors' training. Although the incremental cost per student of the proposed educational activity implementation is relatively low, an organizational budget impact should be expected mainly related to the human resources involved.

KEYWORDS: Costs and Cost Analysis; Resource Allocation; Teaching Methods; Health Education, Dental; Students, Dental.

4.1 INTRODUCTION

Active learning is an instructional approach that places greater responsibility on the learners by giving them more control over their own learning and increasing their motivation and engagement (1). This "student-centred" approach promotes a deeper understanding of the contents (2), has been related to positive outcomes in health education (3–5) and is also seen optimistically under students' perspective (6). Such characteristics have motivated the amendment of many high education programs, including health professionals (7,8), by including these strategies. For this audience, using active learning strategies is especially important, since it promotes the development of critical thinking and problem-solving skills, which are considered essential attributes for a well-trained healthcare team (9).

Besides individual challenges for teachers and learners, the demand for more human and technological resources, some budget limitations and insufficient available time/support provided by the educational institutions may be big deals when implementing a new active learning method (10). In some cases, the lack of resources can be a crucial factor for not adopting active-learning instructional approaches in the program or unviable them in different contexts (11). On the other hand, if educational strategies require different resources to be performed, different "costs" (sometimes, extra costs) should be expected (12,13). Active-learning strategies may require extra time, additional staff and also other resources to be performed. Then, estimating costs expected, or actually spent, when a new educational activity is proposed/implemented is very significant, as part of the activity implementation process. Although little attention has been paid to the economic impact that the educational strategies represent on universities and society (5) and most of the cost studies in dental education are more referred to the student's debts (14–16) than to the cost of acquiring skills or getting a good professional training, economic evaluations are performed in the education contexts to prove whether it is worth allocating more resources to introduce new pedagogical methodologies effectively (15).

A 10-year educational activity has been successfully used for undergraduate students' training in caries detection to substitute the theoretical activity solely with promising effects regarding students' performance (17–19). However, the cost of its implementation (and continuity for those years) was definitely unknown. In that sense, the present paper seeks to estimate the immediate additional cost spent for implementing such an innovative active learning strategy to teach caries detection to undergraduate dental students instead of only using the theoretical expositive class. We also provided a budget impact analysis for the provider educational institution and explored the final cost composition related to different resources added for this activity. We believe this pioneering study can be a starting point in the dental education field, measuring the economic impact of the introduction of active learning in such a context and establishing parameters for future studies linking economy and education.

4.2 METHODS

This article brings a partial-economic evaluation, that used data from a randomized and controlled interventional study on dental education, designed to compare the a theoretical-practical workshop for undergraduate students' training in caries detection to substitute the theoretical activity solely. Table 4.1 summarizes the focused economic research question and the complete structure of the study, according to a specific checklist for that (20). This evaluation considered an immediate time horizon to implement the activity for the first time.

Table 4.1 - Guided structure for cost analysis in Health Professionals Education. Based on Foo, et., al 2020

Study Structure			***Explanation***
1	Study Design	Cost Analysis (educational outcomes were not considered)	Cost of all resources used up (Levin's ingredients method)
2	Study Perspective	Education Provider's Perspective	School of Dentistry of the University of São Paulo - Brazil
3	Alternatives being compared	Conventional strategy (passive learning model) New teaching strategy (active learning)	Lecture/Theoretical class (only) Lecture/Theoretical class + Practical-Laboratorial Training (Complete educational strategy)
4	Contextual factors	The educational setting is a metropolitan public university in Brazil	For this evaluation we consider the total cost spent for implementing and deliver the new teaching strategy for 80 undergraduate dental students.
5	Focused economic research question	From the perspective of a public Brazilian university, how much should be added to implement and deliver an active learning theoretical-practical training for undergraduate students on caries detection?	

Source: The Author

ETHICAL CONSIDERATIONS

For this cost assessment, data gathered in the coordinator centre of a randomized and controlled multicentre study (IuSTC01) was considered (21). This center was used as a reference for leading the complete pedagogical strategy as part of a multicenter trial protocol. The multicenter study protocol was evaluated and approved by the Ethics in Research Committee (CAAE 39632614.0.0000.0075). Participants' data, however, were not used in this study.

STUDY SETTING

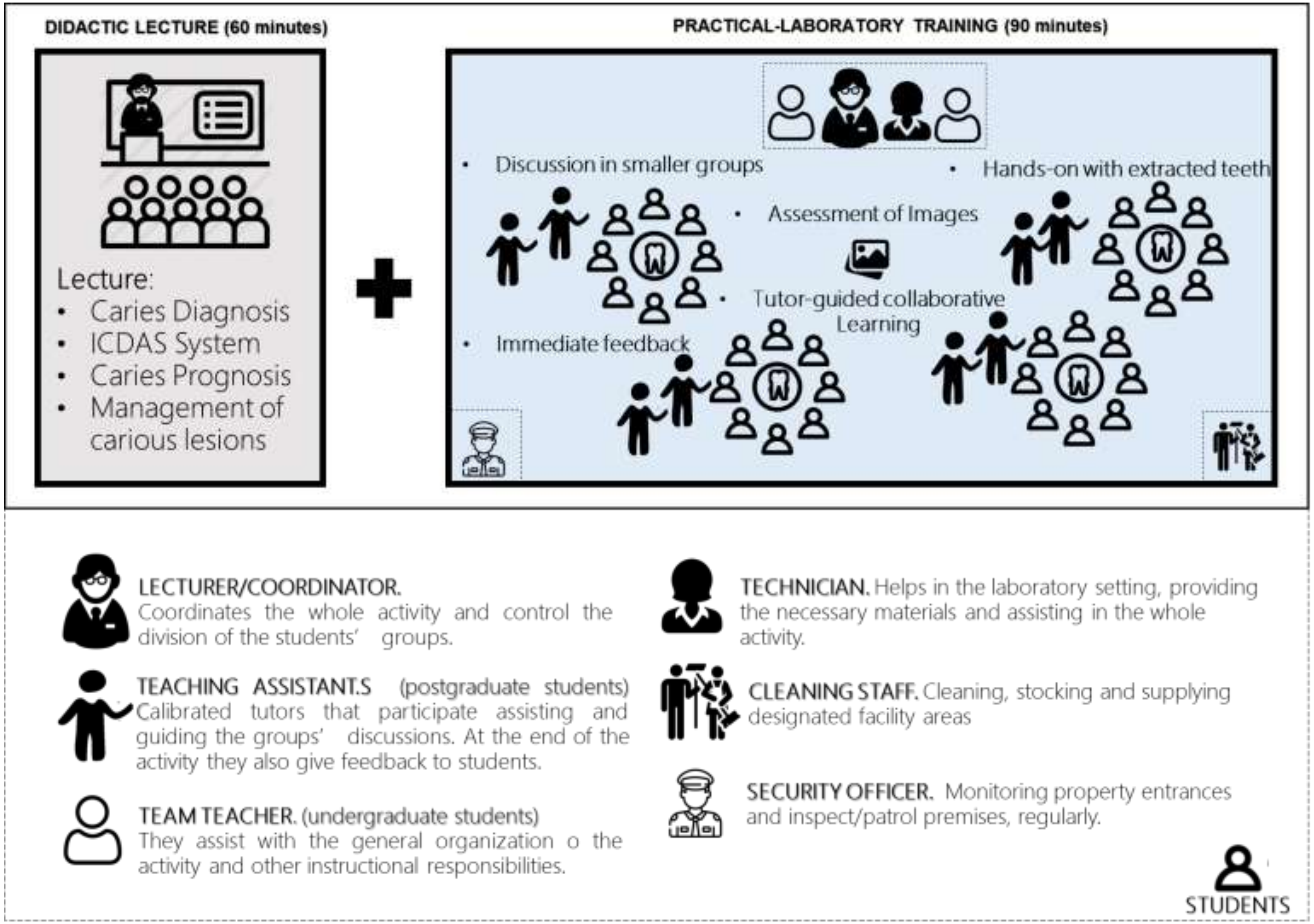
Faculties from the Pediatric Dentistry Department first implemented and delivered the active learning teaching strategy in 2009, under evaluation of the University of São Paulo, Brazil (FOUSP) (17,21). This method, aimed at caries detection training, was mainly based on active learning conjectures and uses resources like simulation, think-pair share, small-group discussions, collaborative learning and immediate personalized feedback from tutors as described below.

INTERVENTIONS

The groups of interventions were different for adding the theoretical-practical workshop to the conventional theoretical class (21) (Figure 4.1).

- Alternative: Didactic Lecture + Theoretical-Practical laboratory training
- Control: Didactic Lecture

Figure 4.1.- Schematically representation of the active learning activity, different actors are involved with their specific responsibilities/assignments during the activity



Source: The author.

In the theoretical class, the students received a didactic lecture, where they were supposed to learn about basic concepts of caries diagnosis, caries assessment and scoring, and other issues related to the management of lesions. The use of ICDAS (International Caries Detection and Assessment System Index) for caries lesions detection was also explained (17,21,22).

When exposed to the workshop, students also participate of preclinical laboratorial training. In training, the students were divided into smaller peer groups of up to 8. One or two facilitators or tutors hosted each group. As part of the activity, tutors initially displayed some images and clinical cases on the computer or TV screen. They encouraged a debate with the group about caries assessments and possible management options. Finally, students assessed a sample of extracted teeth presenting all stages of caries lesions and scored the teeth according to the ICDAS. After scoring teeth, tutors guided a session in which, based on students´ answers, a discussion about each case was initiated so that the students felt confident they knew why their assessments had been done. In the end, the students were supposed to know about the topic, have the practical ability to apply their knowledge, score the surfaces and justify their decision-making.

IMPLEMENTATION OF THE NEW EDUCATIONAL STRATEGY

The implementation of the new strategy described above consisted of four main phases:

1. Preparation of instructional materials (120 minutes)
2. Tutors' training and calibration (90 minutes)
3. Didactic Lecture (60 minutes)
4. Theoretical - Practical-laboratory Training (90 minutes)

Phases 1 and 2 preceded the implementation of the theoretical-practical activity with students, while phases 3 and 4 correspond to the educational intervention itself.

Preparation of instructional materials (120 minutes)

In this phase, the research team (in consensus) elaborates on the students' evaluation sheets and selects the extracted natural teeth that are used for laboratory training. A kit containing teeth presenting all possible ICDAS scores is prepared (Figure 4.2). The correct consensual classification is registered in a key answer sheet that will be used as the reference standard.

Tutors' training and calibration (90 minutes)

A theoretical-laboratory training is carried out with the collaborators that will perform as tutors in the teaching activity. A similar structure is used for undergraduate students, but a more profound discussion is conducted. Besides the specific contents on caries detection, didactic strategies are discussed to standardize the educational intervention for all tutors. Tutors generally were graduate students (MSc and PhD students) that usually performed as teaching assistants in the lab activities.

Didactic Lecture (60 minutes)

This session is carried out in person by a calibrated lecturer, an expert in caries diagnosis and used to give such kind of lecturer. Conventional audiovisual resources are used in a classroom (Figure 4.3a). Lecturer-student interaction is stimulated during the class, guided by the own lecturer or even students' comments and questions.

Practical-laboratory Training (90 minutes)

The workshop training activity is carried out in a laboratory equipped with dental lamps and air/water syringes (Figure 4.3b). Then, the dynamic of the activity follows as described when '*Interventions'* were detailed above.

Figure 4.2 - Kit of extracted teeth prepared for the workshop training phase

Source: The Author

Figure 4.3 - University facilities provided for Lectures (a) and preclinical laboratorial training activities (b)

Source: Pictures gently donated by Braga MM (2014, June).

COST ESTIMATION METHOD

A micro-costing approach was used in this study to estimate the cost for implementing the proposed teaching activity. In this costing approach, we enumerate and value every input consumed for the activity. In addition to that, Levin's ingredients method was used. Apparently this method is commonly used in the scientific literature because it is intended to facilitate the performing of economic evaluations in the educational context (23,24). It comprises identifying and specifying all the "ingredients" needed in educational interventions. Then, it also determines the monetary value of each one of these ingredients. By doing that, we will be able to estimate the total cost of the intervention.

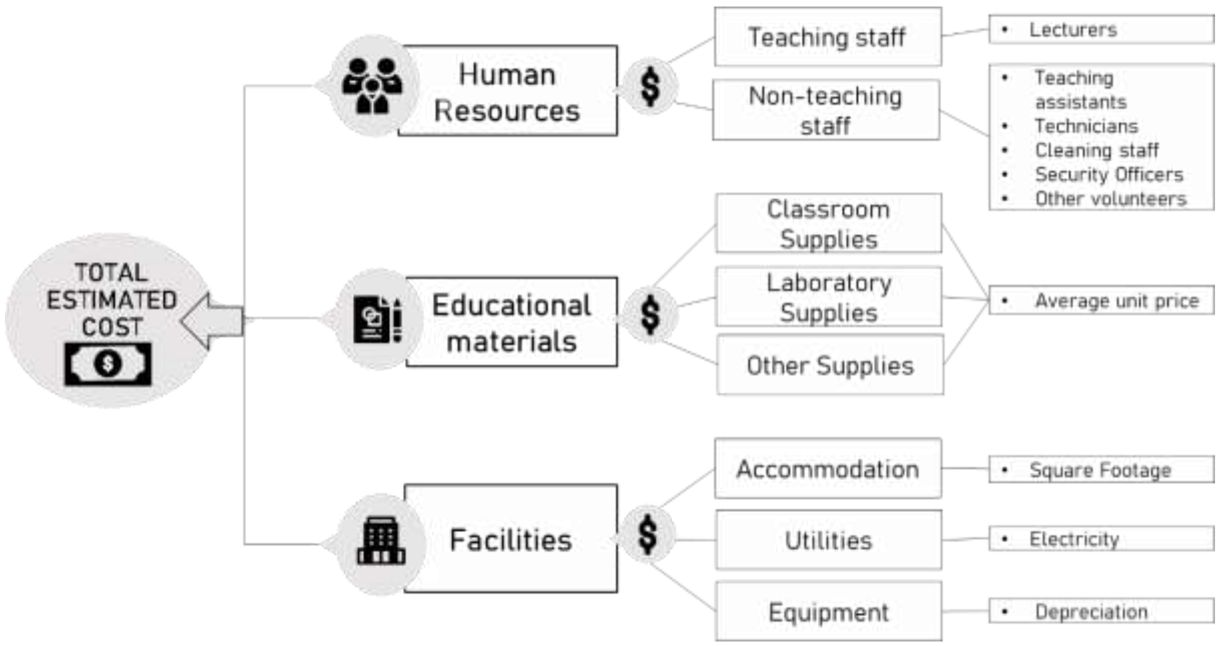
For estimating costs, we consider the activity was delivery for 80 undergraduate students (average composition of the full-time class at FOUSP). The four phases described above were considered for estimating the costs of the two interventions compared in this essay, considering the necessary resources for their execution. Resources were organized for each one of the phases and recorded in three main categories: human, material and structural resources. The final composition of costs was obtained from the sum of all these categories (Figure 4.4).

HUMAN RESOURCES

The costs of the teaching and non-teaching staff were calculated considering the time spent (in hours) by those involved in each phase of the activity. Figure 4.1 better illustrates the involvement of the different professionals in the execution of the active learning activity with their dedication time and assignments. That time was multiplied by the average correspondent income for each category. For academic personnel (professors and postgraduate students performing as teacher assistants and tutors) the official institutional salary values were used as a reference (25,26). For the non-academic personnel and "voluntaries", the minimum wage for the state of São Paulo, as suggested by Brazilian Federal Law (16.665), was considered (27).

The mean value referent to a working day was used in the analysis, assuming 8 hours for a working day.

Figure 4.4 - Final cost composition



Source: The author.

EDUCATIONAL MATERIALS

Instructional materials were explicitly used for the teaching activity and were provided by the centre (textbooks, supplies, implements, tools, etc.). We considered the average market price of each product unit multiplied by the number of units registered as used. The extracted teeth used in the workshop training activity had no cost because they were donated by the local bank of human teeth. Only costs with materials for preparing them for the activity, as the flasks and other laboratory materials, were computed for the evaluation. Prices were collected in three different stores, and a mean of these values was used as a reference.

FACILITIES

In facilities, we consider the costs related to the use of the institutional facilities during the educational activity, divided into three subcategories: accommodation, utilities and equipment (Figure 4.4). The accommodation cost was estimated per hour of use of the area occupied by the students (m2) (classroom: 208.83m2, laboratory: 307.12m2). The m2 price was calculated based on the current municipalities values/taxes for the region and following the didactic environments recommendations from the manual provided by the University of São Paulo (28). Electricity cost was measured following the same methodology, multiplying the value of municipal taxes by the average consumption during the activity time.

Equipment and maintenance costs were calculated considering total time for each phase in hours. This time was multiplied by the average depreciation time per hour of used of each one. The value per hour was obtained considering the total cost of the equipment considering a useful life of 5 years for computers and 10 years for the other equipment).

We collected information about all resources above, explicitly used in the organization and implementation of the activity in Pediatric Dentistry in 2021 with the full-time course students. All the prices were collected in Brazilian Real (BRL) in 2021 and then converted into International Dollars ($) using the purchasing power parities (PPPs) for Brazil in 2021 (Exchange rate: 2.526131) (29).

DATA ANALYSIS

The incremental cost per student for implementing the laboratory activity in addition to the theoretical class was estimated. Subtotals of each of the four described phases were considered for the active-learning activity to permit comprehension of cost composition for different stages of implementation. The total cost for implementing the complete strategy in 80 students (organizational budget impact) was also calculated.

Monte-Carlo simulations were used to estimate the uncertainties. For that, we assumed a triangular distribution of subtotal costs of each stage of the activities. The value obtained in the reference sample was used as the mean of the distribution.

Maximum and minimum values were obtained varying ±10% in each one simulating other possible contexts. Then, the interquartile interval was calculated to estimate the uncertainty in the values calculated.

For this preliminary analysis, cost adjustments were not necessary because we assumed an immediate "single event"- educational intervention. Then, it was not required to consider prices over time, as inflation or discounting values (30).

4.3 RESULTS

The total time to implement this active learning strategy for teaching cariology was approximately 6.5 hours, while for the didactic lecture, solely, approximately 1 hour was spent. For assisting 80 students as considered, 25 collaborators were involved in implementing and effectively applying the pre-specified educational approach. Students were clustered into 8 different groups, which performed the activity in one unique round (or two consecutive rounds allocating the same tutors on two different occasions).

The total cost spent to implement and deliver an educational strategy for training 80 undergraduate students in caries detection was $684 (approximately $9 per student) (Table 4.2), generating an incremental cost for the workshop implementation for substituting the theoretical class solely around $8 per student.

The forth phase (practical-laboratory training) accounted for the bulk of the activity cost, comprising about 50% of the total cost (Table 4.2). When we analyze the cost composition, more than 70% of the money was spent on human resources. Staff participation and its costing have been expressed in Table 4.3, showing how the values were distributed among staff actors and different tasks performed during the active learning activity (Table 4.3, Figure 4.1). Other minor cost components are divided equally between the remaining expenses in implementing the activity (Table 4.2).

For further applications, we could predict a saving of up to 40% of the total cost if we assume that there would be no need to repeat the phases of preparing the didactic materials and training the tutors (assuming no substitution would be necessary for further occasions).

Table 4.2 - Cost composition of educational activities analyzed in this economic evaluation and their interquartile intervals (IQI) obtained by Monte-Carlo simulation models – median (IQI). Highlighted cells may be phases that could be reduced or extinguished in case of successive activities been done

LECTURE + PRACTICAL-LABORATORY TRAINING							
	STAGES	**Duration time**	**Cost of Human Resources ($)**	**Cost of Educational Materials ($)**	**Cost of Facilities ($)**	**Cost Per Stage Median (IQ)**	**Stage Percentage Cost (%)**
1	Preparation of instructional materials	1 hour class	79.83	0	16.03	**95.86** (93.05 - 98.66)	14.02%
2	Tutors' training and calibration	1.5 hour class	153.52	0	37.35	**190.87** (184.72 – 195.87)	27.92%
3	Didactic Lecture	1 hour class	38.02	3.05	08.03	**49.10** (48.25 – 51.16)	7.18%
4	Practical-laboratory Training	1.5 hour class	218.99	104.29	24.43	**347.72** (93.05 - 98.66)	50.86%
	Total Cost Median (IQI)		**490.37** (484.19 – 501.17)	**107.34** (107.60 – 111.37)	**85.85** (80.70 – 83.52)	**683.50** (672.49 – 696.07)	**100%**
			72%	16%	12%		
Complete educational strategy (Implementation and delivering)		**6 hours**	**$ 683.50** (672.49 – 696.07)				**100%**
Cost per Student		**-**	**$ 8.54**				
DIDACTIC LECTURE							
		Duration time	**Cost of Human Resources ($)**	**Cost of Educational Materials ($)**	**Cost of Facilities ($)**		**Stage Percentage Cost (%)**
Only Lecture		1 hour class	38.01	7.72	8.03		7.18%
			78%	6%	16%		**100%**
Total cost Median (IQI)			**$ 49.10** (48.25 – 51.16)				
Cost per Student			**0.24**				
Incremental Total Cost			**$ 634.46**				
Incremental Cost per student			**$ 7.93**				

Source: The Author

Table 4.3 – Distribution of values according to staff participation

Implementation Phase	***Number of people involved***	***Description***	***Number of involved***	***Mean cost per hour (R$)***	***Mean cost per hour (PPPs)***
Preparation of instructional materials	3	Coordinator	1	86.22	34.08
		Teacher assistant	1	12.50	4.94
		Team teacher	1	2.27	0.90
Tutors' training and calibration	19	Coordinator	1	86.22	34.08
		Tutors	16	10.51	4.15
		Team teacher	2	2.27	0.90
Didactic Lecture	1	Lecturer	1	96.18	38.02
Practical-laboratory Training	25	Coordinator	1	86.22	34.08
		Teacher assistant / Tutors	16	10.51	4.15
		Team teacher	2	2.27	0.90
		Lab Technician	1	49.53	19.58
		Cleaning staff	4	27.56	10.89
		Security Officer	1	6.25	2.47

Source: The author.

4.4 DISCUSSION

In our findings, we highlighted an institutional education should provide an extra budget or an incremental investment of less than for each student of approximately 8 dollars per student or maybe 700 dollars per year considering the group of students to provide this innovative active-learning strategy to train undergraduate students in detecting caries lesions. Are these figures inexpensive? Probably yes, but that can depend on many factors related to the interested stakeholders, like the learning effect this teaching method could promote in the students, even if the institution has a sufficient budget for implementing that. Taking into account that implementing active learning strategies represents an effort to transform education by improving the teaching methods; it should also be considered an "economic investment".

Active learning has been widely recommended for the education of health professionals, like dentists, because it increases student engagement, promotes peer collaboration, enhances reflection and helps to develop better reasoning and critical thinking skills as problem-solving abilities (3,31). Hence, training dental students actively or in situations as similar as possible to reality improves the overall cognitive process (32,33). Indeed, the educational effects of the active learning strategy used for caries detection have been previously explored and published (18). Those aspects are essential not purely for students' academic performance but because health professionals' education directly affects the health and well-being of patients (patient’s outcomes) (34).

On the other hand, extra resources have been demanded to achieve such effects and those resources have economic value. Undoubtfoully, the activity lasts more than the traditionally used (the didactic lecture). In fact, the whole activity encompasses this one and complements possible gaps, expected to be a more prolonged activity. Besides, the systematic used comprehends other preparation phases (preparation of instructional materials and tutors’ training and calibration) that are essential to have the activity set before actual implementation. Theoretical classes also demand previous preparation. However, active strategies may be even more time-consuming and expensive than the delivery phase (35). Pathways to guide the activity should be prepared to guarantee all the class objectives can be reached at the end, even if different ways might have been chosen during the activity, as a student-centred approach is being used. This aspect should be even more relevant if we consider that a team of professionals should be required to deliver the activity, as discussed in this paper.

The team training phase is an important aspect that cannot be ignored, because it is also an important "input" considering the costs associated. In the theory of the team formation process (36), if the teaching team is not well aligned and calibrated, several failures may be incorporated in the application of any activity. The team's construction involves several stages, and it is essential to understand whether these collaborators' inputs and outputs can modify the dynamics of the teaching activity (37), reinforcing the relevance of “spending” time and funds in training collaborators that will be involved in implementing a teaching activity. Working as a functional team is a great challenge, but this factor could not influence the success of the group and the teaching-learning activity.

Another important finding emerging from this study is the magnitude of the human resources in the improvement of an additional benefit to the learning process, as we are discussing for caries detection. More than 70% of the total amount was invested in the task force to implement the activity. Indeed, human resources and even extra personnel dedication time are related to the more expensive component when implementing student-centred teaching strategies (38). Several tutors should be involved in the teaching activities to achieve the laboratory training goals. Smaller groups of learners guided by one or two tutors guarantee that the active learning fundaments (such as thin-pair share or collaborative learning and immediate feedback) were maintained. The proper conduction of discussions in the smaller groups was essential and would not be possible in a massive group of students (as an entire group of 80 students, for example). Thus, the more tutors we can have participating, the more individualized the teaching process becomes and enables the effective participation of learners in the discussions receiving immediate feedback for their questions (39,40). In a smaller group, the student may be more comfortable and have more opportunities to actively participate compared to when he/she was in a regular classroom with all students grouped.

Specifically, for this educational activity, the teaching staff was mainly composed of graduate students, who act as assistant professors (as part of their academic training). As, in most cases, these graduate students only receive a subsidy from the university, this strategy may save financial resources when such type of activity is implemented. Indeed, implementing an activity like that only involving regular faculties must be more expensive and, sometimes, prohibitive given the personnel required. On the other hand, other strategies may be found to minimize these deals and were published elsewhere as result of IuSTC initiatives (Chapter 1).

Although some extra budget should be prepared to these investments in discussed phases of implementation of this active-learning strategy in caries detection, an approximately 40%- saving can be expected in further occasions. If a fixed staff is maintained to deliver the activity yearly, it would not be necessary to retrain the teaching staff or replace the teaching materials. Indeed, for some active online learning strategies for continuing medical education, it has been shown the initial costs of planning, developing and implementing tend to be amortized in subsequent offers (41). Based on that, to implement yearly the activity under consideration for 80 students, considering this possible discussed variation, an extra budget from 400 to 800 should be planned. At this stage, graduate students' involvement should be considered an additional source of expenses since extra time and money should be regularly invested in retraining the new members of the tutoring team.

The activity-learning strategy proposed here to train in caries detection demands, by nature, a different educational environment if compared to a regular class. Despite not being the most expressive cost component, the structural costs perform approximately 10 times more than the traditional teaching approach (the didactic lecture). The use of simple laboratories would be enough to carry out the activity described here and having very expensive equipment or "luxury" facilities is not required. However, the time of use of such environment (more than to a specific supply or greatest technologies) was valued and considered in the present economic evaluation.

The teaching materials were provided to the students in this study and we can cite that the most important element for the practical caries detection simulation experience was the sample of extracted teeth that were prepared for this activity. We must understand that the preparation of some instructional materials during the implementation phase will normally require an initial cost, but in future applications of the activity this cost will amortized and will not be very relevant, because it is already prepared. Except for in some cases, where it will be necessary to change a sample tooth, for example, or other specific material due to the wear caused by the use. Therefore, there will be a new cost associated, but it will be minor and will not affect the overall cost of the activity. On the other hand, if we would need to prepare a new complete set of teeth, the cost would probably be higher, because not only the material is necessary but also a team selecting and preparing that sample set.

The application of student-centred teaching approaches can transform education. In Cariology, it seems that lectures are still the most used manner to teach students about this topic (42). Nevertheless, as we demonstrated in this paper, it would be possible to introduce new teaching strategies without an abusive cost. However, implementing new active teaching strategies can often be challenging for some institutions since they have been described as costlier and more time-consuming, discouraging their implementation (11,43,44). We believe this paper can bring an important contribution to this area of research by understanding the required resources to implement and deliver active learning strategies, as described here. Then, we can estimate the feasibility of applying it in other contexts. Although a Brazilian perspective has been used, we used Monte-Carlo simulations considering a distribution of different values around the central value recorded. In this way, we believe other national and international contexts were represented.

Taking together all the results presented here, we believe that any economic investment that will be made in education should be evaluated from a broader perspective, considering several variables and scenarios (45). Many types of economic evaluations can be used in education. Still, in this paper, we focused in performing a cost assessment of an active learning strategy for teaching caries detection to undergraduate dental students. As we considered the costs separately from the learning effects, despite informing many relevant aspects of strategic and budget planning, we are limited in not addressing conclusions about the economic efficiency of the teaching strategy. Another limitation is that learner cost was not considered in this study because the costs were exanimated only from the education provider perspective.

To evaluate the efficiency of resource allocations, we would need to analyze the cost of the activity together with the educational outcomes (20). Besides, selecting more than one perspective is essential (13,30,46) to observe if we would have different results under different glances and if an educational method worth the time and monetary investments for all the interested stakeholders (teachers, students, patients, providers, health services). Finally, exploring if the long-term effects could outweigh the additional costs initially invested is relevant. Researchers must consider that some tools and analyses can help education decision-makers (however rarely used) (24). One example is the breakeven analysis that can be performed to guide decision-makers in understanding how economic benefits could be perceived after some subsequent reapplications of the teaching activity over time (47). Such long-term analyses could demonstrate some speculations we raised in this paper.

The findings of this study, detailing and estimating the costs of a teaching method, could be used as a starting point for future comparisons with other studies and to other centres that used the same teaching methodology. Unfortunately, until now, most studies only consider costs in dental education relate to students' debts (14–16) and not those for acquiring skills or getting good professional training. Cost reporting in education research is still infrequent and incomplete (44,48). This issue has probably received limited attention in literature because of the difficulty in assigning monetary values to a set of teaching activities or to a whole educational process (13,49). However, recent publications have reinforced the importance of exploring and reviewing the concepts of "costs" and "value" in health professionals' education (20).

We believe the present study can also open a new generation of studies and evolve the relationship between cost and educational outcomes in dental education. Further research is needed to understand the economic and non-economic implications that may influence the efficiency of the teaching methods. Knowledge about this topic is important to allocate economic resources better, as well as, to improve education quality. Estimating the costs of educational activities is also imperative to enable future comparisons across other university settings.

In conclusion, the cost registered per student was not high. Less than ten dollars per undergraduate student should be invested in caries detection training for these students using the active-learning approach. However, a relevant economic impact exists on the educational institution yearly, majorly related to the human resources involved in planning, preparing and delivering these activities.

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5 CHAPTER IV: TUTORED ACTIVE-LEARNING STRATEGY TO UNDERGRADUATE STUDENTS' CARIES DETECTION TRAINING: COSTLY BUT WORTH IT – MULTICENTRE TRIAL-BASED ECONOMIC EVALUATION

ABSTRACT

Active learning mediated by tutors effectively develops dental students' practical skills in caries detection. However, an additional budget is necessary to implement such a new idea in an educational context. The remaining question is if the immediate effects of this educational strategy justify using these additional resources in this direction. Then, a multicentre trial-based economic evaluation was planned to answer that question. The educational provider's perspective (educational institution) and immediate effects were adopted. Data was collected in an educational multicentre trial (IuSTC-01). The new alternative theoretical-practical laboratory training (active learning method) had its costs and educational effects compared to the traditional training method, lecturing (passive learning method). The costs of the teaching strategies were estimated considering the human resources, materials and university facilities. Different educational effects were observed as advantages for the learning method, and cost-effectiveness analyses were performed considering them. Probabilistic sensitivity analyses were performed to handle uncertainties. Incremental costs and effects and Net Monetary Benefits (NMB) were calculated. Acceptability curves were used to explore decision-making under different thresholds. On average, an incremental cost of $25 per student was needed to implement the new activity. A 4% to 15% increase in effects over the students' practical skills should be expected from his investment in such methodology. Assuming a ceiling ratio of $10 per student, the strategy is considered 70% cost-effective for developing skills in scoring caries severity (NMB; 95%CI: 14.56; 14.01-15.10). This probability increases to 100% if the skill developed is assessing caries lesion activity status (NMB; 95%CI: 126.25; 125.87-126.62). The tutored theoretical-practical active-learning training is a cost-effective alternative to improve the students' caries detection practical skills in undergraduate dental education in substitution of traditional lectures, being a worthy investment to be disseminated in educational institutions.

5.1 INTRODUCTION

The quality of education of dental professionals and health care workers in general impacts patient outcomes and can influence public health (1). Hereby, medical and dental educational institutions are always concerned about providing their students with the best possible training (2). In that sense, introducing new instructional approaches suitable with the students' needs and different learning styles is recommended, along with the complete modernization of the teaching-learning process (3).

Active learning methodologies represent a great alternative to enhance dental students' competencies since they promote more interaction and engagement of learners (4) and exhibit superior educational outcomes (5). Active learning mediated by tutors effectively develops dental students' practical skills in caries detection, as demonstrated in Chapter 2. The learning effects of these two alternatives were carefully assessed in a multicentre controlled randomized trial (6) led by a group of researchers working on some Initiatives for undergraduate Students' Training in Cariology (IuSTC) (7). Nevertheless, an additional budget is necessary to implement such a new idea in an educational context, especially due to a massive investiment in human resources for acting as tutors and guiding the activity delivering (Chapter 3). The remaining question is if the immediate effects gained with the educational strategy justify using these additional resources allocated. When implementing new teaching methods is essential to consider that. Therefore, evaluating the teaching methods, not only in their educational outcomes but also in their economic aspects, seems very relevant (8).

Economic evaluations within health professionals' education are still little explored in the literature (9), probably because it is challenging to understand education as an economic investment (10). More recently, this subject has drawn the attention of researchers and educators, stimulating the development of a series of guidelines and recommendations for conducting and interpreting economic analyses in health professions education (11,12). Nonetheless, an intersection between dental education and economics remains challenging and apparently scarce.

This multicentre trial-based economic evaluation aimed to bring effective responses if investing in the new proposed tutored active learning strategy to developing practical skills to caries detection is an efficient way of allocating resources when substituting the "standard" lecture-based approach. Eleven dental educational institutions participated in the main trial, so the teaching methods were tested in real-world settings and different worldwide contexts. This paper will focus on the educational provider's perspective and the immediate education effects achieved by the strategy. Secondly, the economic impact of the strategy on student-centred outcomes will also be explored.

5.2 METHODS

STUDY DESIGN

This multicentre trial-based full economic evaluation was conducted using data from a multicenter controlled and randomized study focused on educational and economic outcomes related to a new learning activity. The Local Ethics previously approved the research protocol for the IuSTC-01 trial in Research Committee (CAAE 39632614.0.0000.0075). The eleven dental educational institutions that were involved in the study also approved it in their committees. Undergraduate dental students from different classes and graduation years of those institutions were included. Further details regarding the main trial are available in the published study protocol (6) and in Chapters 2 and 3. This manuscript will be reported according to Consolidated Health Economic Evaluation Reporting Standards (CHEERS) (13).

TARGET POPULATION, SETTING AND LOCATION

Undergraduate dental students registered in an educational institution are our case base population. As nested in a large multicentre trial, this evaluation aims to permit data generalizability to most dental schools worldwide. No restriction about the time of the student's graduation is made.

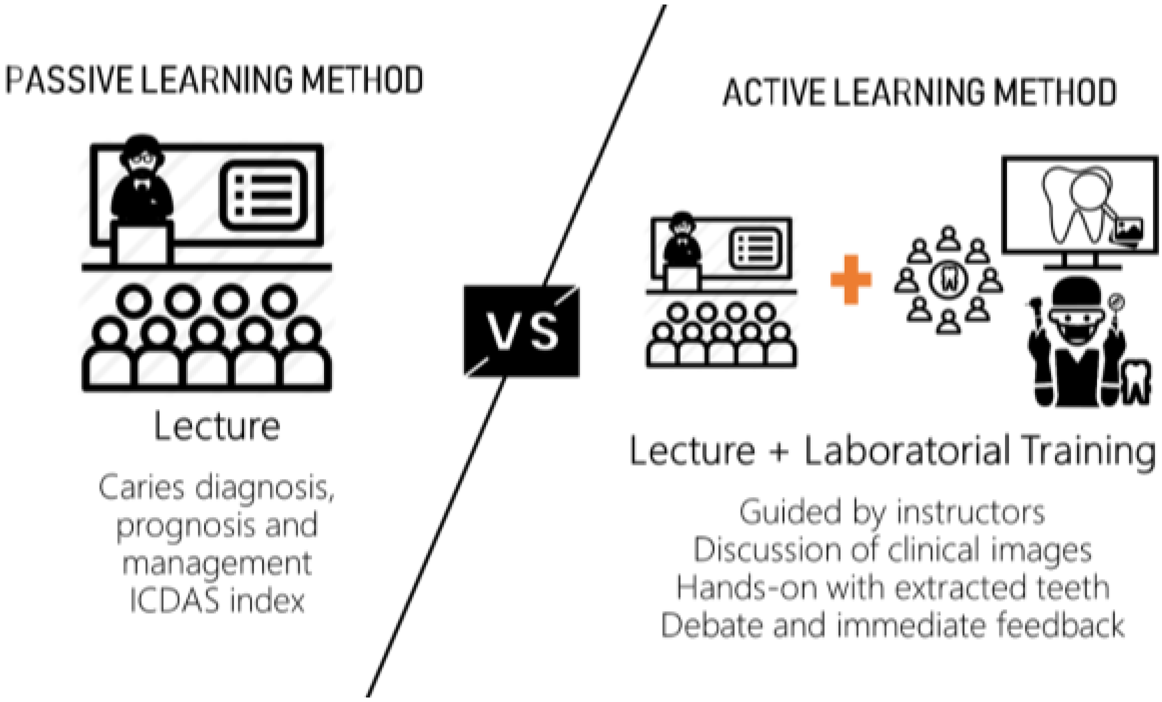
STUDY PERSPECTIVE, TIME HORIZON

The provider's perspective (the dental educational institution that offers the training method) was adopted. The immediate effects of the intervention are considered (immediate time horizon). As short-time outcomes were set, this first strategy implementation evaluation assumed no discount rate.

COMPARATORS

The teaching strategies that are being compared in this study (tutored active-learning training vs lecturing) are illustrated in Figure 5.1 and were broadly explained in previous chapters. The didactic lecture is considered the traditional strategy to teach students about caries detection (14) that is being considered to be substituted by a new teaching method that uses more active learning resources.

Figure 5.1 - Teaching strategies considered for the full economic evaluation performed in the present study



Source: The author.

CHOICE OF EDUCATIONAL OUTCOMES

The main outcome considered is the student's practical skills for caries detection, since such skills acquisition was the main educational effect of the proposed teaching strategy and the primary outcome for the multicentre reference trial. The overall achievement of students (0 to 100), considering the correct assessments performed, was established as the effect. This effect was considered separately, concerning the practical ability to score caries severity and to assess caries lesion activity status. To be calculated for each skill, the number of correctly scored/classified surfaces was divided by the total number of assessed surfaces. Then, an x100 coefficient was used to obtain the percentual value.

Other secondary effects were considered for additional economic evaluations. One of them is the ability of decision-making related to caries detection (a 0 to 10 score given by the proportional number of correct answers in detecting severity, assessing activity and choosing the correct management for caries lesions in simulated clinical cases). The other is the students' self-perceived performance (a student-reported score from 0 to 5 by which she/he judge her/his performance on a practical assessment performed immediately before). These outcomes, then, generated other secondary economic evaluations to be considered as complimentary to the primary ones. More details about each outcomes assessments can be found in Chapter 2.

MEASUREMENT OF EFFECTIVENESS

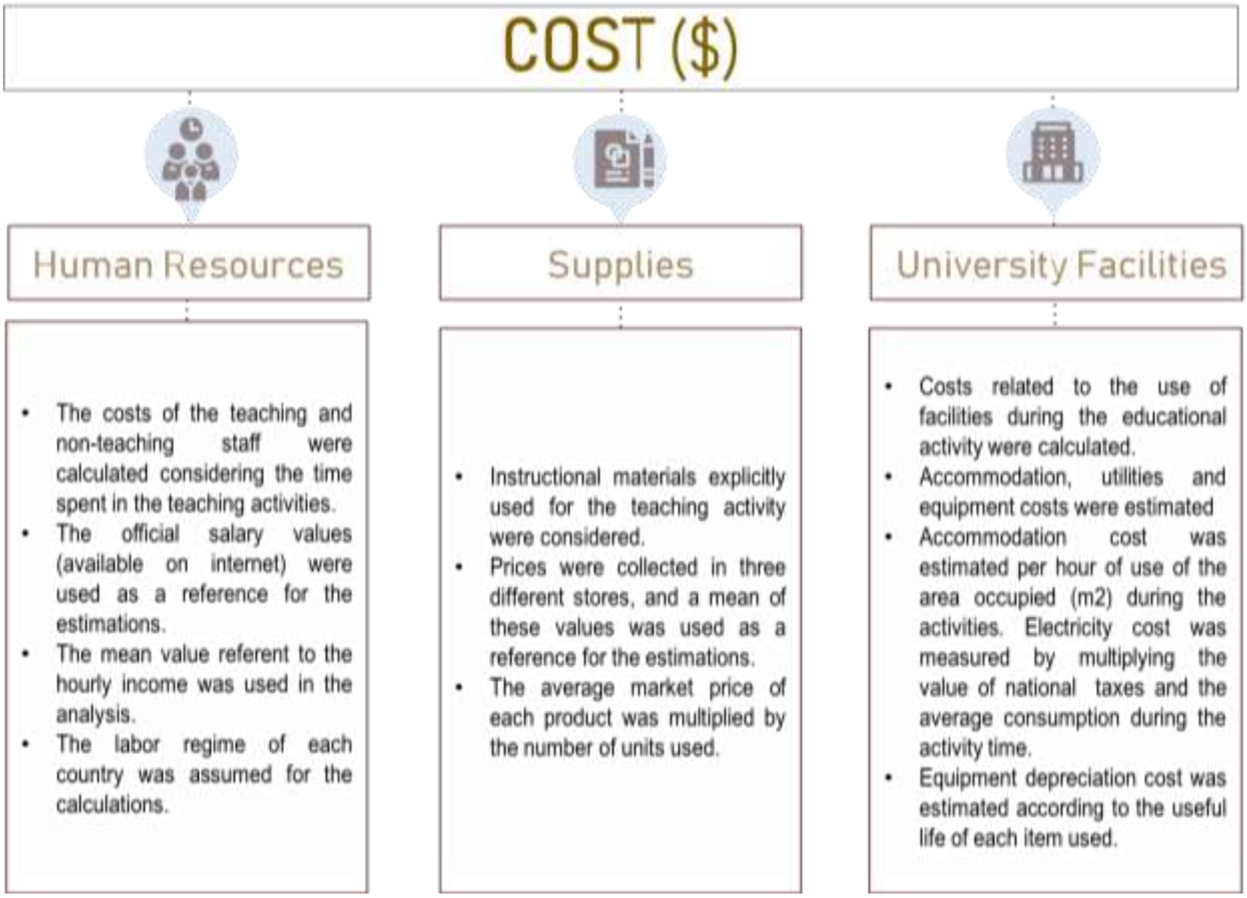
All estimates were derived from a large multicentre educational trial data (outcomes)(6). It is a single pragmatic study that, even considering its limitations, may approximate the results of a real-world scenario of dental education worldwide. The study involved 11 educational centres, and more than 1,000 students enrolled. Besides, different educational, cultural and geographical contexts are represented. More details about the trial may be found in other chapters.

ESTIMATING RESOURCES AND COSTS

All the resources used in each centre (of the main trial) to perform the teaching activities were identified, listed and priced. A micro-costing approach was adopted for this assessment, followed by the "ingredients method" described by Levin et al. (6). More details about the assumptions used to estimate the final cost are described in Figure 5.2. A cost repository containing the reference values and sources of information was prepared and may be openly accessed.

Three main categories were considered to organize the resources: 1) Personnel or human resources involved in the teaching activities, 2) Instructional materials provided by the institution and 3) Facilities. Costs for implementing the activity for the total number of students registered per class were calculated. Finally, all costs were estimated per student.

Figure 5.2 - Micro-costing approach was adopted for the estimation of costs divided in three main categories



Source: The Author

CURRENCY, PRICE DATE, AND CONVERSION

All resources considered in this study were first valued in the local currency of the participant centres (dental schools) and then, converted to international dollars ($). For the conversion, we used Purchasing Power Parities (PPPs). Reference values were collected from the website (15) and considered the reference year 2021, which was the one available on (February 2023). As the multicenter study had the participation of different institutions worldwide, the PPPs adjusted economic statistics and facilitated cross-country cost comparisons.

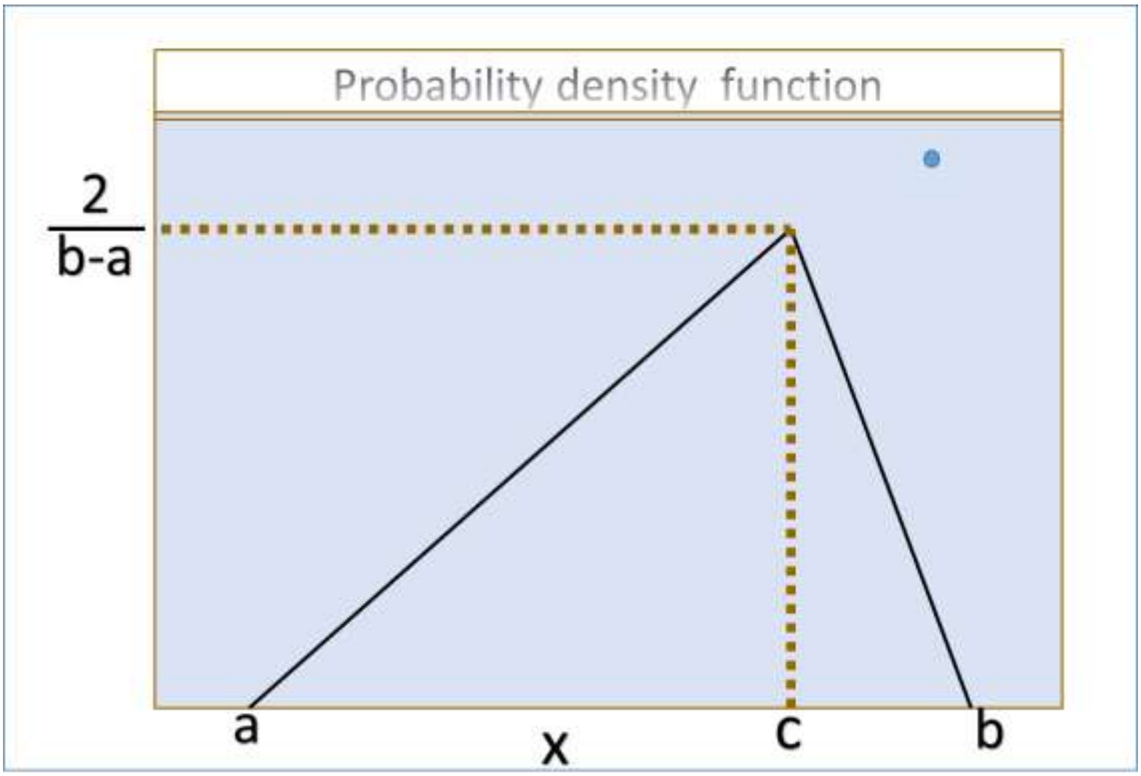
ANALYTICAL FRAMEWORK

The analyses presented in this chapter are predominantly intention-to-treat (ITT) analyses, or more appropriately, intention to implement the educational strategy. The costs were considered for an entire class of students to who the interventions were delivered. However, the non-respondent students' effects were not computed at this time. We did not consider the imputation of effects for absent or not-willing to participate students not to assume extreme values. We avoided assuming a zero value that would not be real since we certainly had any residual effect from students' backgrounds). Besides, we also averted the use of an arbitrary value since parameters for conditional imputation were unavailable since trial data had been anonymously recorded. We believe this choice may produce a final estimate that, for a first attempt at economic evaluation, will reflect the investment even on these students who did not attend the activity contributing to the skills development of those who were present.

The calculated cost and the effects of the strategies were summarized using the mean and standard deviation (SD) with 95% of confidence intervals (95% CI). Costs and effects were compared using Stata17 software (Stata Corp LP, Texas, USA). Effects were compared between Poisson regression analysis strategies and the costs using the bootstrapped quantile median regression. The clustering effect on centres was used to adjust the comparisons and the estimates.

A Bayesian approach was also adopted to explore the uncertainties of the studied parameters. Firstly, the data distribution for effects was checked and related parameters were obtained using XLSTAT (software 2021 version, Paris, France). As the costs were assessed by classes and equally calculated by the number of registered students in it, we opted not to use the sample distribution of costs. Then, we assumed a triangular distribution. The mean cost for each intervention was set as the as mode for the distribution (c). Extreme values were set as the minimum (a) and maximum (b) costs for the intervention in different centres (Figure 5.3). This methodological strategy may have permitted different costs to be generated for different students without being influenced by size of the centres.

Figure 5.3 – Illustration of a triangular distribution used for the analysis



Source: The author

Monte Carlo simulations were also performed (10,000 simulations), considering the distributions defined above and the final summary measures were obtained. The simulations initially considered the sample distribution of relative effects, and then a final distribution of the absolute effect was generated. This absolute effect (simulated) was considered for the subsequent analyses.

The delta (Δ) cost and delta (Δ) effects were calculated with the difference of costs and effects of the teaching strategies. The deltas (Δ) were resulted from the difference between the individual values for costs or effects of the new teaching strategy (lecture + training) in substitution to the traditional teaching strategy (lecture only):

ΔCOST = LECTURE ***cost*** – LECTURE+TRAINING ***cost***

ΔEFFECT = LECTURE ***effect*** – LECTURE+TRAINING ***effect***

Then, Δ values were plotted in a cost-effectiveness plane (CE plane) to permit the interpretation. The proportion and location of points in the different quadrants of the CE plane were evaluated. The cost-effectiveness (CE) of the new teaching strategy was calculated in terms of Net Monetary Benefits (NMB), following the equation: NMB= Incremental effect x ceiling ratio – Incremental cost. To calculate the NMB, two potential willingness to pay (WTP) values were set: $5 and $10, considering this as potential decision makers' willingness to pay for an additional educational benefit in his/her institution. If the net benefit were positive (higher than zero), then the educational intervention strategy was considered to be cost-effective, as the benefit (learning effect) outweighs the costs (ceiling ratio or maximum value that an institution will pay). If the net benefit is negative (less than 0), the intervention is not cost-effective, as the costs outweigh the benefits (additional unit of effectiveness). The NMB and their 95% CIs were calculated for each studied effect. Different ceiling ratios were tested to check if the probability of cost-effectiveness changed. Based on that, the acceptability curves were plotted considering those probabilities.

5.3 RESULTS

1,190 undergraduate dental students were included in the main trial (IuSTC-01). They were similarly divided into two groups, according to the teaching strategy that they received: lecture (only) = 589 students (50%) and lecture associated with the new active learning training = 601 students (50%). Of them, 57% (n=684) were from the first-years of graduation and 43% (n=506) from the last-years. All the participant centres, the geographical location and the distribution of participants are displayed in Table 5.1.

LEARNING EFFECTS

The educational outcomes of the two educacional approaches used in the main trial and the primary and secondary outcomes of the protocol study were broadly explored in previous chapters. Table 5.2 reports the more relevant findings regarding the effects we found in the multicentre trial.

In this manuscript, otherwise, some students' skills were summarized using the student as the unit of analysis (different from other attempts). Students's practical skills were, on average, higher in trained students than in those who only attended the didactic lecture when they scored severity of caries lesions (Table 5.2). Different effects per centre are presented in Table 5.1, reflecting uncertainties for the target population. When assessing activity status, such an effect was still more evident (Table 5.2). The same was not observed for ability in decision-making derived from caries detection (Table 5.2). The student-centred endpoint also reflected differences between groups exposed to different strategies (Table 5.2).

Table 5.1 – Effects achieved in the different centers for the main learning outcome (student's practical performance on scoring caries lesions) and costs expressed in international dollars ($)

ID	**Educational Institution**	**Location**	**Sample Allocation (N)**	**Teaching Method**	**Total strategy Cost ($)**	**Cost per student ($)**	**Effect % achievement**
1	University of São Paulo	São Paulo, Brazil	174	Only Lecture	49.10	0.61	61%
			187	Lecture + Training	396.82	4.96	64%
2	Federal University of Santa Maria	Santa Maria, Brazil	56	Only Lecture	51.37	0.46	40%
			56	Lecture + Training	1087.40	9.71	45%
3	School of Dentistry, University of São Paulo	Bauru, Brazil	45	Only Lecture	50.61	0.58	41%
			43	Lecture + Training	423.00	4.81	53%
4	Federal University of Pelotas	Pelotas, Brazil	23	Only Lecture	86.32	1.76	41%
			26	Lecture + Training	380.31	7.76	48%
5	Federal University of Piauí	Piauí, Brazil	59	Only Lecture	112.81	0.95	51%
			60	Lecture + Training	438.01	3.68	60%
6	Federal University of Mato Grosso do Sul	Campo Grande, Brazil	16	Only Lecture	48.62	1.39	54%
			19	Lecture + Training	273.91	7.83	59%
7	University of Guadalajara,	Jalisco, Mexico	19	Only Lecture	26.01	0.68	72%
			19	Lecture + Training	225.66	5.94	77%
8	University of Copenhagen	Copenhagen Denmark	33	Only Lecture	691.33	9.88	57%
			37	Lecture + Training	2119.14	30.27	67%
9	University of Porto	Porto, Portugal	73	Only Lecture	2630.84	19.20	61%
			64	Lecture + Training	3712.40	27.10	59%
10	El Bosque University	Bogotá, Colombia	38	Only Lecture	428.25	5.63	47%
			38	Lecture + Training	1370.25	18.03	53%
11	Indiana University School of Dentistry	Indianapolis, United States	53	Only Lecture	155.44	1.48	58%
			52	Lecture + Training	8209.26	78.18	64%
IuSTC – 01 Overall Results		**Multicenter Trial**	**601**	**Only Lecture**	**337.15**	**3.92**	**55%**
			589	**Lecture + Training**	**1694.20**	**16.58**	**60%**

Source: The author

Table 5.2 – Mean values of effects and costs registered in the IuSTC multicenter trial

EFFECTS				COST ($) International Dollars		
LEARNING EFFECTS		**LECTURE**	**LECTURE + TRAINING**		**LECTURE**	**LECTURE + TRAINING**
Development of practical skills for detecting caries lesions	Mean (CI)	**54.68** (47.80-61.57)	**59.63** (54.46-64.80)	Mean (CI)	**$3.92** (-1.30-9.15)	**$16.58** (0.64-32.53)
	(coefficient= 0.08; 95$CI: 0.03 to 0.13, p=0.001)					
Identify the activity status of caries lesions	Mean (CI)	**43.99** (42.61-45.38)	**59.12** (58.06-60.18)			
	(coefficient= 0.30; 95%CI: 0.21 to 0.38, p<0.001)					
Decision-making in simulated clinical cases (0-10 points)	Mean (CI)	**5.74** (5.56-5.91)	**5.77** (5.57-5.97)	**(coefficient = 4.99; 95CI: 3.06-6.92) p<0.001**		
	(coefficient=0.007, 95CI: -0.03 to 0.04). p					
STUDENT-CENTRED OUTCOME						
Self-reported performance	Mean (CI)	**1.56** (1.32-1.80)	**1.78** (1.62-1.93)			

Source: The Author.

COST OF THE TEACHING STRATEGIES

The mean cost per student to deliver an innovative active learning strategy for caries detection was about $17 compared to approximately $4 for the lecturing (Table 5.2). The mean cost registered in each institution for both teaching approaches applied (Table 5.1). The range of costs varied among the different centres. The lecture ranged from a minimum cost of $26 to a maximum of $2631. The training activity also highly varied (from $226 to $8209). In all centres, the cost of the new pedagogical strategy always exceeded the cost of the lecture (Table 5.1).

Human resources were generally the most relevant component of final cost composition in all scenarios for both educational interventions (Table 5.3). Some institutions (n=2), materials cost comprised the highest investment in the active learning strategy. Facilities represented the most relevant resource in both teaching strategies for only one centre (Table 5.3).

COST-EFFECTIVENESS ANALYSIS

Based on the results of simulated data, the alternative educational strategy (tutored active-learning training) demanded a higher investment when substituting the conventional lecture (Table 5.4). An increase in the educational effects of the new strategy was observed as well (table 5.4). The combination of costs and the effects of developing such practical skills resulted in a positive NMB value, when we assume $10 as the ceiling ratio (Table 5.4). But, that was different if we assume a lower ceiling ratio ($5 per student), the strategy is considered 70% cost-effective for developing skills in scoring caries severity at a ceiling ratio of $10%. a slight increase in the probability of cost-effectiveness would be reached for the same skills development when other other celling ratios are considered (Figure 5.4, Table 5.4).

Table 5.3 – Type of resources and their distribution in the final composition of costs. Highlighted cells represent the category that was more representative for the final cost. Their colors only represent the group they are related to

Dental School	Interventions compared	Total cost $ (100%)	Personnel Cost (%)	Materials Cost (%)	Facilities Cost (%)
El Bosque University, Bogotá, Colombia	Only Lecture	**428.25**	41%	2%	57%
	Lecture + Training	**1370.25**	44%	20%	37%
University of Porto, Porto, Portugal	Only Lecture	**2630.84**	2%	0%	98%
	Lecture + Training	**3712.40**	7%	4%	89%
University of Copenhagen, Copenhagen Denmark	Only Lecture	**691.33**	94%	2%	4%
	Lecture + Training	**2119.14**	74%	24%	2%
Indiana University School of Dentistry, Indianapolis, US	Only Lecture	**155.44**	99%	0%	1%
	Lecture + Training	**8209.26**	51%	27%	22%
University of Guadalajara, Jalisco, Mexico	Only Lecture	**26.01**	90%	6%	4%
	Lecture + Training	**225.66**	32%	65%	3%
School of Dentistry, University of São Paulo, Bauru, Brazil	Only Lecture	**50.61**	75%	6%	19%
	Lecture + Training	**423.00**	48%	45%	7%
Federal University of Pelotas, Brazil	Only Lecture	**86.32**	88%	1%	11%
	Lecture + Training	**380.31**	59%	33%	8%
Federal University of Santa Maria, Santa Maria, Brazil	Only Lecture	**51.37**	74%	7%	19%
	Lecture + Training	**1087.40**	22%	75%	3%
Federal University of Piauí, Brazil	Only Lecture	**112.81**	67%	3%	30%
	Lecture + Training	**438.01**	57%	31%	12%
Federal University of Mato Grosso do Sul, Campo Grande, Brazil	Only Lecture	**48.62**	78%	2%	20%
	Lecture + Training	**273.91**	60%	32%	8%
University of São Paulo, São Paulo, Brazil	Only Lecture	**49.10**	77%	6%	16%
	Lecture + Training	**396.82**	65%	27%	8%

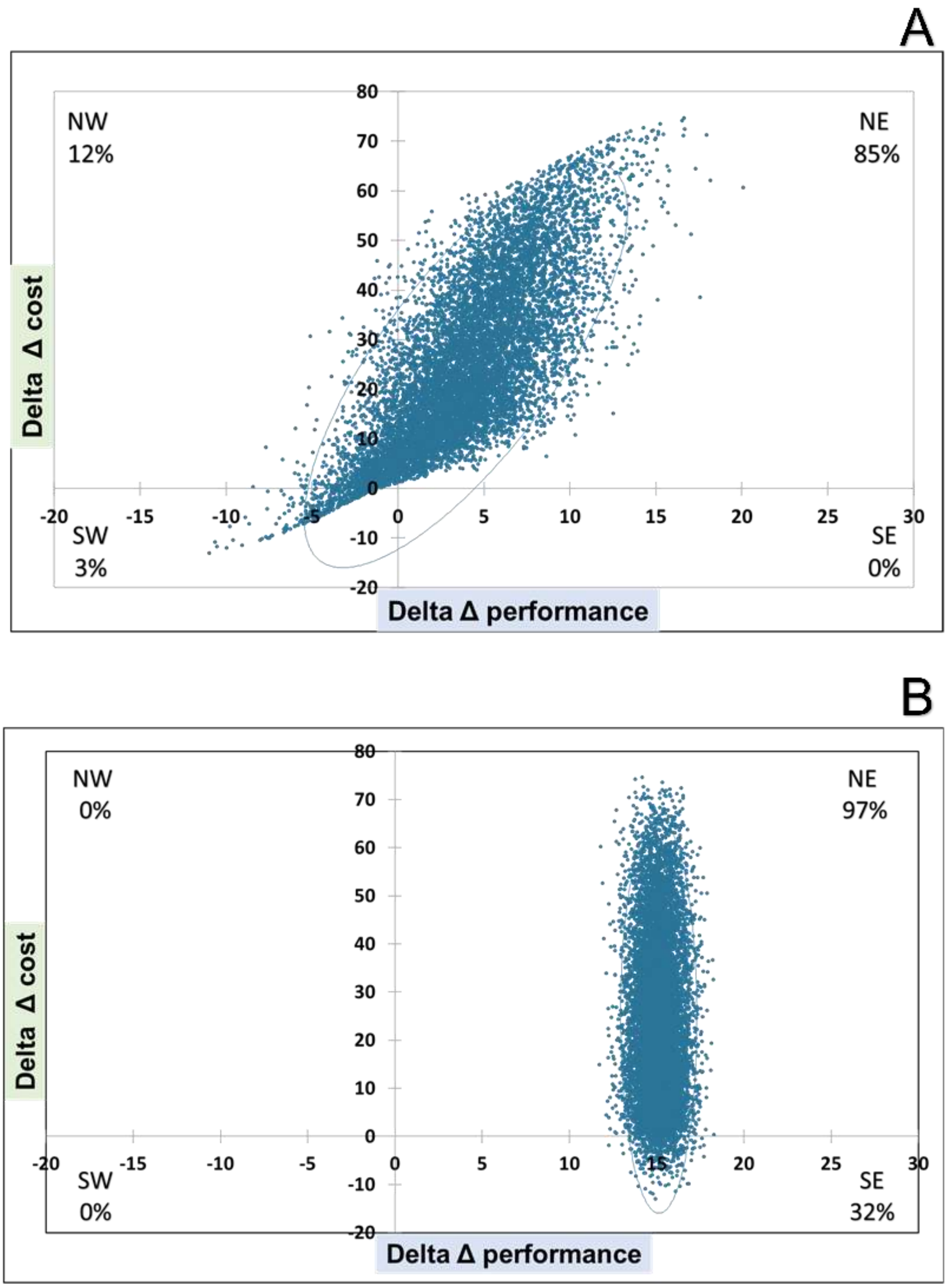
Source: The author.

This probability increases to 100% if the skill developed is assessing caries lesion activity status (Table 5.4, Figure 5.4), even if the decision-maker's willingness to pay for the activity was of only $2 per student (Figure 5.4).

Exploring the uncertainties in CE plane related to students' practical skills development, we can observe a greater concentration of simulated points in the North east (NE) and South west (SW) quadrants (Figure 5.4 A). A more expressive agglomeration on east quadrants is evident in Figure 5.4B, reflecting a better allocation of resources when the method is used to develop students' abilities to assess caries activity status (Figure 5.4 B).

For improving the students' ability/attitude for clinical decision-making and perceiving a better practical performance, the alternative teaching strategy had less probability of being cost-effective in the same thresholds used (Table 5.4). Despite threshold variation, slight changes would be observed (Figure 5.5).

Figure 5.4 - Cost-effectiveness plane of 10.000 simulations, showing the Delta Costs in international dollars and Delta effects. A. Effect on student`s practical performance for caries detection. B. Effect on student performance in identifying the activity status of caries lesions



Source: The author..

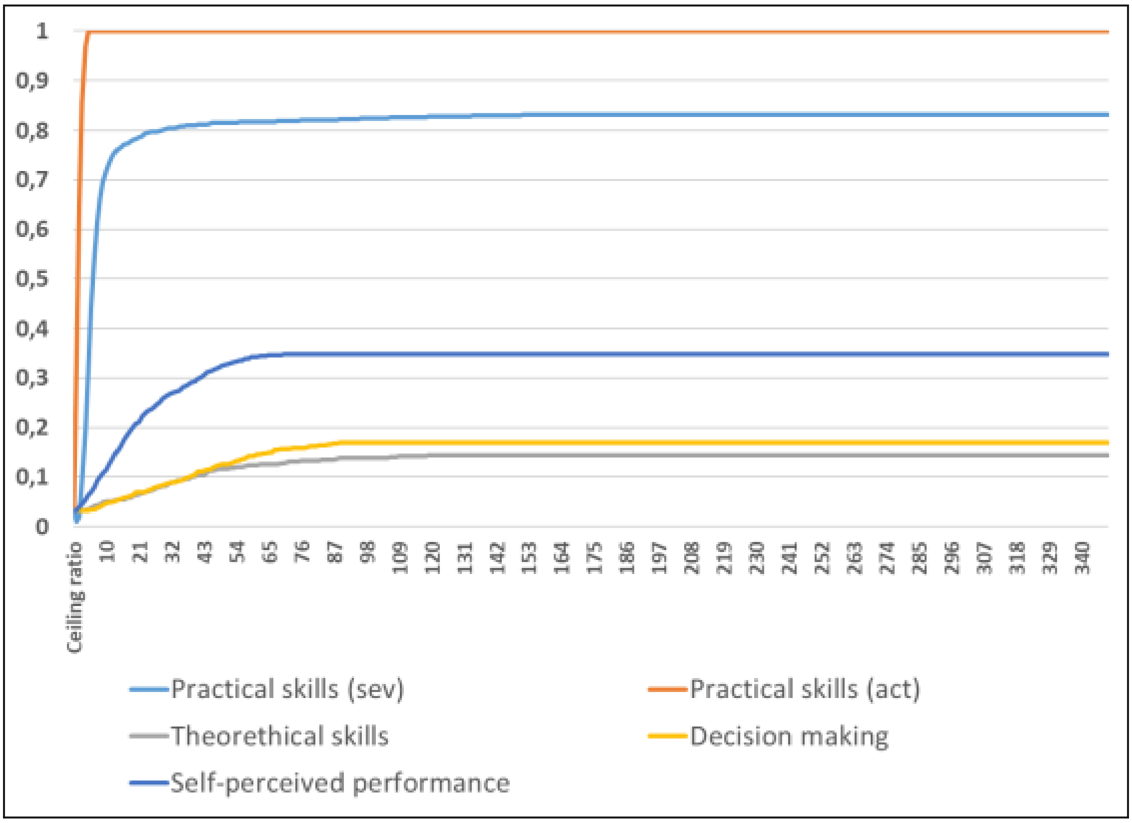
Table 5.4 – Summarized data from the simulated sample is presented for costs and effects of the teaching strategies. (CE probability= probability of being cost-effective).

COST ($)			
	LECTURE	**LECTURE + TRAINING**	**Δ DELTA**
Mean (CI)	**7.86** (7.78-7.94)	**32.81** (32.49-33.13)	**24.95** (3.87-4.02)
Median (IQ)	**7.23** (4.55-10.74)	**30.28** (19.52-44.31)	**22.51** (11.76-36.51)
International Dollars			

EFFECTS					Ceiling ratio of $ 5 (WTP)		Ceiling ratio of $ 10 (WTP)	
LEARNING EFFECTS		**LECTURE**	**LECTURE + TRAINING**	**Δ DELTA**	**Net-Monetary Benefit (NMB)**	**CE Prob. (WTP $5)**	**Net-Monetary Benefit (NMB)**	**CE Prob. (WTP $10)**
Development of practical skills for detecting caries lesions	Mean (CI)	**54.68** (54.62-54.74)	**58.63** (58.59-58.68)	**3.95** (3.88-4.03)	**-5.46** (-5.45-4.95)	**31%**	**14.56** (14.01-15.10)	**70%**
	Median (IQ)	**54.68** (52.60-56.76)	**58.63** (57.07-60.19)	**3.94** (1.33-6.54)	**-5.19** (-13.50-2.99)		**13.97** (-3.95-32.61)	
Identify the activity status of caries lesions	Mean (CI)	**44.00** (43.99-44.01)	**59.12** (59.11-59.13)	**15.12** (15.10-15.14)	**50.65** (50.31-50.99)	**99%**	**126.25** (125.87-126-62)	**100%**
	Median (IQ)	**44.00** (43.52-44.48)	**59.12** (58.76-59.48)	**15.12** (14.52-15.73)	**52.72** (38.70-63.98)		**127.63** (113.40-140.14)	
Solve clinical cases (0-10 points)	Mean (CI)	**5.75** (5.74-5.79)	**5.77** (5.74-5.79)	**0.07** (0.07-0.08)	**-24.60** (-24.93- -24.27)	**3%**	**-24.25** (-24.58- -23.91)	**4%**
	Median (IQ)	**6.00** (5.33-6.67)	**6.00** (5.33-6.67)	**0.00** (0.00-0.00)	**-22.23** (-36.12- -11.46)		**-21.89** (-35.90- -11.18)	
STUDENT-CENTRED OUTCOMES			**LECTURE + TRAINING**	**Δ DELTA**	**NMB (WTP $5)**	**CE Prob. (WTP $5)**	**NMB (WTP $10)**	**CE Prob. (WTP $10)**
Self-reported performance	Mean (CI)	**1.56** (1.32-1.80)	**1.78** (1.62-1.93)	**0.23** (0.20-0.24)	**-23.50** (-24.18- -23.50)	**6%**	**-22.73** (23.11- -22.35)	**10%**
	Median (IQ)			**0.00** (0.00-0.022)	**-21.73** (-35.74- -10.52)		**-21.14** (-35.91- -8.59)	

Source: The author.

Figure 5.5 – Acceptability Curves considering different educational and student-centred effects from the active-learning activity



Source: The Author

5.4 DISCUSSION

Innovations in any area may accompany a tricky question: investing resources in such an idea (strategy, intervention etc) is worthwhile? The answer is not always easy to achieve and may require different points of view to be digested (the economist's and educators' points of view). This paper began with this challenging question, bringing as the novelty a purpose to be used when training dental students in their practical skills for caries detection. After looking into the results, at this point, we can affirm the proposal is an efficient way of allocating educational resources, depending on your expected outcomes.

In dental education, several economic evaluations could be performed to assess the pedagogical strategies' economic efficiency (16). Nevertheless, the main important issue is to first clearly establish the learning outcomes desired to explore and state how the "effect" and costs should be measured (i.e. knowledge acquisition, knowledge retention, development of practical skills, units of behaviour change, etc.). Since the idealization of the educational strategy, its main purpose has been evident. The activity was designed to promote practical training, exploration of various practical experiences and continuous feedback among tutors, students and their peers. For that, a practical ability should be considered as the desired effect. Among all effects tested in the economic evaluations conjointly here, the most relevant efficiency in allocating resources to improve was exactly the students' practical skills. For other secondary abilities included in economic evaluations here presented, such as those related to students' ability of decision-making or students' perception, the strategy is not a cost-effective option.

Even demanding a higher investment to use the new teaching method, the magnitude of such investments per student was not prohibitive. We do not have a classical/standard willingness to pay (WTP) threshold for achieving an educational outcome. It could vary depending on many factors, such as the local setting, type of educational approaches, and even the perceived value of education in different countries or cultures (17). That is why we assumed two different thresholds to explore the findings of cost-effectiveness analysis. On the other hand, our decision rules should be reasonable. As an educational decision-maker, can I invest in a benefit that can be favourable for 70-to-100% of my students, costing less than 10 dollars? Certainly, the free or renewable budget should be decisive for that. Besides, a budget impact analysis may show for the number of students we have to teach, how much I will need for that and permit the decision-making on incorporating or not such activity on curricula (18). Finally, decision-makers should consider that such investment goes beyond student formation/training. As the educational activity cost is highly concentrated on human resources and staff is prepared, motivated and engaged in preparing and delivering such activities, an additional long-term benefit, which was not considered in the present analyses, may also be weighed.

On the other hand, the magnitude of the effect should also be considered. At an idealist educator's first glance, one can say any benefit is valid, and if only one student benefited, she/he would be compensated for that. However, unfortunately, in the real world, investing in that may not be feasible. A special challenge is experienced because different learning outcomes have different values for different actors. How much is a better ability in detecting caries? We are not often able to quantify. Thinking about the repercussion of this effect may then help us judge the results we found. Let us convert the effect to the benefit of having a dental professional who may have he/she accuracy for detecting caries and assessing their activity status increased. Imagine a patient will have his/her dental surfaces (n=128) by a trained professional, who graduated in one of the institutions that which adopted the new training strategy. The patient would have additional correct diagnosis in approximately 5 surfaces (delta=4), which may have received a more adequate treatment.

Full economic evaluations compare two or more interventions, considering their costs and effects in producing a certain outcome (19), being an attempt to join these two spheres. Those types of analysis are very important tools that can assist health and educational decision-makers. However, they are unfortunately still rarely used in education (16). Besides, when performed, they constantly fail in important methodological aspects (20). A recent systematic review demonstrated that it is usual to find studies describing some educational interventions, affirming that they are "cost-effective" strategies not even performing any economic evaluation or merely report the costs spent (9).

The teaching strategies that were compared in the present economic evaluation were cautiously delineated in previous studies of our group and were tested in different countries, and university settings (multicenter research protocol) (6). The first results obtained in the trial demonstrated that we were right in that assumption (21) and that the method it is effective, but as a secondary outcome in the trial, we also wanted to determine if the new method would be a cost-effective substitute. The estimated NMB in the present study resulted in a high probability of the teaching strategy being cost-effective (77 to 100%). NMB is a strategical approach in economic evaluations that is calculated by subtracting the total costs of the intervention from the total benefits that it generates (22). It is a manner to "value" the effect, using a certain threshold for willingness to pay. Different ceiling ratios were adopted in our analyses, and acceptability curves were constructed to check the influence of different thresholds on decision-making. We opted to use this measure because it is a linear measure that facilitates the interpretation of results for decision-makers.

As the present study, economic analysis performed alongside clinical trials has the advantage of offering more precise measurement of costs and effects because they were assessed during trial and within the same population (23). Additionally, using pragmatic and multicentre trials to feed these evaluations is an advantage in incorporating uncertainties to be handled and explored in the economic evaluations (24) and maximizing their power of generalizability for different contexts (25).

Another important aspect of economic evaluations is evaluating multiple perspectives (20,26,27). Understanding if an educational method is worth the time and monetary investments for all the interested stakeholders (teachers, students, patients, providers, and health services) is relevant. For our study, we only considered the educational provider's perspective. We wanted to understand the feasibility of implementing this teaching activity in the multicenter trial's different settings or dental schools. Still considering such perspective, we assumed the cost generated to deliver the activity should be fully considered independently of the students who receive the benefit.

On the other hand, we could not assume the same for the effects. Although imputation is useful in economic evaluations (28), its use on educational effect as we intended may be challenging. Missing data in our trial comprised those randomized students since, for logistical reasons, all registered students were randomized. However, these students were not exposed to the educational intervention. Besides, they could not have their characteristics identified since data collection was anonymous, limiting the conditional imputation. Therefore, if considering a null or arbitrary value, we could create a very different situation from those observed in an educational context. Then, even given their limitations, such methodological options might have approximated our findings from the real-world scenario.

Finally, it is important to understand that investments in education may have long-term benefits for individuals and public health because a more educated professional can offer accurate diagnoses for patients. Further analysis can help to understand whether introducing the new teaching strategy is a more efficient option to replace the conventional lecture, even considering long-term outcomes. Adjoint or independent strategies should be created and tested to provide other efficient options for developing those skills that were not covered by the present educational alternative until now.

It is concluded that, the tutored theoretical-practical active-learning training is a cost-effective alternative to improve the students' caries detection practical skills in undergraduate dental education in substitution of traditional lectures, being a worthy investment to be disseminated in educational institutions.

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ANNEX A - CHEERS 2022 Checklist

	Item	Guidance for Reporting	Reported in section
		TITLE	
Title	1	Identify the study as an economic evaluation and specify the interventions being compared.	137
		ABSTRACT	
Abstract	2	Provide a structured summary that highlights context, key methods, results and alternative analyses.	137
		INTRODUCTION	
Background and objectives	3	Give the context for the study, the study question and its practical relevance for decision making in policy or practice.	138
		METHODS	
Health economic analysis plan	4	Indicate whether a health economic analysis plan was developed and where available.	144
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	139
Setting and location	6	Provide relevant contextual information that may influence findings.	140
Comparators	7	Describe the interventions or strategies being compared and why chosen.	140
Perspective	8	State the perspective(s) adopted by the study and why chosen.	140
Time horizon	9	State the time horizon for the study and why appropriate.	140
Discount rate	10	Report the discount rate(s) and reason chosen.	140
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	142
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	142
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	142
Measurement and valuation of resources and costs	14	Describe how costs were valued.	142
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	144
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	n/a
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	n/a
Characterizing heterogeneity	18	Describe any methods used for estimating how the results of the study vary for sub-groups.	n/a
Characterizing distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	146
Characterizing uncertainty	20	Describe methods to characterize any sources of uncertainty in the analysis.	145/146
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (e.g., clinicians or payers) in the design of the study.	n/a
		RESULTS	
Study parameters	22	Report all analytic inputs (e.g., values, ranges, references) including uncertainty or distributional assumptions.	147
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	147
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	n/a
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	n/a
		DISCUSSION	
Study findings, limitations, generalizability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could impact patients, policy, or practice.	157
		OTHER RELEVANT INFORMATION	
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	160
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	n/a

6 CHAPTER V: ADAPTING AND DELIVERING ACTIVE LEARNING STRATEGIES FOCUSED ON CARIES DETECTION – CASE STUDY AND ECONOMIC IMPACT OF TWO DENTAL SCHOOLS EXPERIENCES

ABSTRACT

In 2020 due to the restrictions imposed by the coronavirus pandemic, the teaching methodologies had to be adapted to allow social distancing and avoid contamination at university dental programs. This study aimed to describe the instruction adapting experience of two different universities during the COVID-19 pandemic period, modifying their teaching approaches to be able to continue training dental students for caries detection by using tutoring and active learning resources. Costs of implementing the adapted approaches, considering all used resources were also estimated. The resources were valued and organized into three main categories: human resources, instructional materials and facilities. The cost was first estimated in the local currency for the 2020-class and then converted to international dollars using Purchasing Power Parities (PPPs). The School of Dentistry of the University of São Paulo (FOUSP), Brazil applied online tutored teaching strategies with gamified content for n=80 students. The Indiana University School of Dentistry (IUSD), USA adopted a hybrid teaching model involving both online and in-person activities for n=105 students. Developing and delivering the teaching strategies cost $5091 for FOUSP ($64 per student) and $8209 for IUSD ($78 per student). In the overall composition of costs, the human resources category represented the most expensive ingredient for the FOUSP distance activities (98%). Conversely, at IUSD, in a hybrid teaching model, the infrastructure costs were the most representative. We conclude that, for both institutions, positive results were observed in performing adapted methodologies during the pandemic. Pandemic adaptations to the teaching learning activities on caries detection require some creativity and investment to overcome the challenges. However, the same challenges represent opportunities to reinvent the teaching methods and enhance the quality of cariology education, bringing relevant innovations to potentially be incorporated on the routine basis.

Keywords: Dental education; Active learning; Cariology; Hands-on. Covid19; Pandemic

6.1 INTRODUCTION

The highly transmissible coronavirus disease emerged in China at the end of 2019. At that moment, probably no one could predict the greater dimensions that this deadly respiratory disease took and nor the consequences that we are still observing in the present time (1). In 2020, the World Health Organization (WHO) declared a global pandemic and a state of emergency. Different countries' governments started to take measures to keep people safe and prevent the virus from spreading. The strict measures adopted were full lockdowns, boarders closure, household disinfection, and mask-wearing (2). Despite those actions, countries like the United States and Brazil still revealed some intern deficiencies/difficulties in controlling the contagions, leading the two countries to lead number of deaths in the world for a long time.

The SARS-COV-2 pandemic brought many challenges, but its effect on the health and education sectors was the more problematic. Besides the several deceases registered quickly and a higher workload for the health personnel (3), there were other problems, like learning disruption in all education levels and increasing absenteeism rates (4). Almost certainly, the entire education sector was severely impacted when all in-person activities had to be interrupted to prevent more contaminations. Therefore, students and professors were forced to adapt to the new teaching-learning conditions in which remote activities were mandatory.

In dental education, the circumstances were not different. Although dental care of patients must have been continued, teaching methods demanded adaptation to maintain students' learning activities and disciplines. Some reports of teaching experiences during the pandemic are found (5–8). Nevertheless, as far as we know, they are not focusing on exploring a specific teaching-learning framework in different contexts or analyzing its economic aspects. So, in this paper, we want to explore these issues that emanated from the modifications made in two dental educational institutions, one in Brazil and the other in the United States, that reinvented themselves to continue applying a preset teaching method for caries detection in undergraduate education. The adaptations occurred at different times of the pandemic, according to each country's conditions imposed by the particular health situation. By bringing these issues to light and reporting these two experiences, we can help identify areas for improvement and highlight the challenges that need to be addressed by educators. Besides, we aimed to raise some insights about the costs of these adapted teaching methods to discuss the magnitude of such impact on an educational system.

6.2 METHODS

This paper describes the experience of two different dental schools in teaching and training undergraduate dental students in the detection of caries lesions during the COVID-19 pandemic and the crucial actions that must be taken to maintain the educational quality (contents) and student's engagement. These institutions were: The School of Dentistry of the University of São Paulo (FOUSP), Brazil and Indiana University School of Dentistry (IUSD), United States. Both institutions actively participate in the Initiatives for undergraduate Students' Training in Cariology (IUsTC). Then, a similar active-learning activity was used to train undergraduate students. Still, in each of them, some adaptations/variations were necessary to meet the particular context of the institutions and face the stage of the pandemic they were going through. This paper will bring adaptations for the first class since the pandemic 2020-classes (FOUSP=80 students and IUSD=105 students).

ORIGINAL TEACHING METHOD

The tutored-mediated theoretical and laboratorial teaching methodology was originated and first implemented in 2009 in the Pediatric Dentistry discipline, University of Sao Paulo (9). Since 2015, several universities have been using it motivated by a multicentre project they participated in (10). The teaching-learning strategy consists in three important moments that are summarized in next.

1. *Didactic Lecture* an approximately 60-minute conventional in-person lecture, carried out in a lecture hall, where the caries diagnosis process is contextualized, together with important aspects to be evaluated for caries

prognosis and the progression of caries lesions. This lecture also explores using the ICDAS as a system to aid visual inspection. Afterwards, the possible management decisions in relation to the different lesion severity stages and activity status are also explored.

2. *Tutored-mediated activity with images*. Students are divided into smaller workgroups composed of 8 to 10 participants. Each group has one or two tutors that project 30 images (clinical photographs) representing different lesion severities and activity and will later discuss with the students the assigned ICDAS scores, activity and possible management approach, and the reasoning behind that.

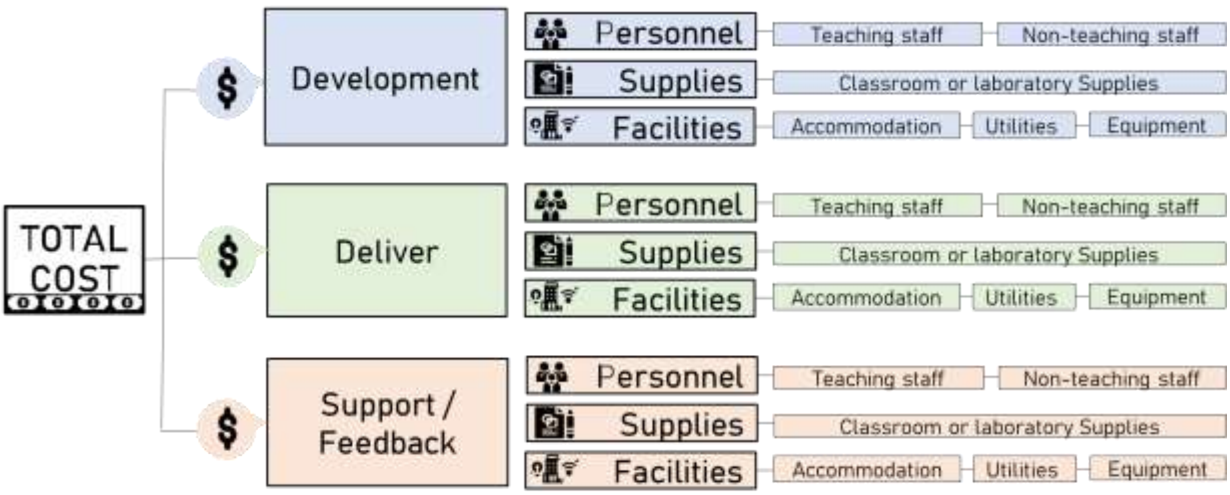
3. *Tutored-mediated lab training practice with extracted teeth.* This hands-on training experience is carried out in a student dental simulation laboratory. Students are asked to visually assessed and score (ICDAS) a sample of extracted teeth presenting caries lesions at different severity stages. This assessment is performed using air/water syringe, dental light and a ball-ended dental probe. Tutors also interact with the students, discussing, guiding and correcting their answers, providing individual feedback. One or two students' answers initiate discussion, and others are incentivized to participate.

As described above, the teaching strategy was originally idealized to work on caries detection contents with the students by combining both "passive" and "active" educational resources. That approach has proved effective in promoting learning and developing practical skills for caries detection clinically, as well as well accepted among students, as demonstrated in Chapter 2. Nevertheless, the strategy was initially designed for an "in person" format, and given the safety guidelines recommending social distancing during the COVID-19 pandemic, some modifications were needed to guarantee the student teaching-learning processes for caries detection at this sensitive period.

COST ASSESSMENT

In addition to reporting the teaching experiences lived during the COVID-19 pandemic, a detailed analysis of all the resources and costs associated with developing and delivering the adapted methodologies is also presented. This analysis used a micro-costing approach to identify and measure each resource needed to implement the educational activities. A more detailed description of the methodology for cost assessment is presented in Chapters 3 and 4. The total cost of each strategy was calculated by aggregating the cost of each cost component of three main categories: personnel, equipment and supplies. Figure 6.1 illustrates the final composition of costs and the assumptions for the calculation.

Figure 6.1 - Final composition of cost, considering the development and delivering phases



Source: The author

6.3 RESULTS

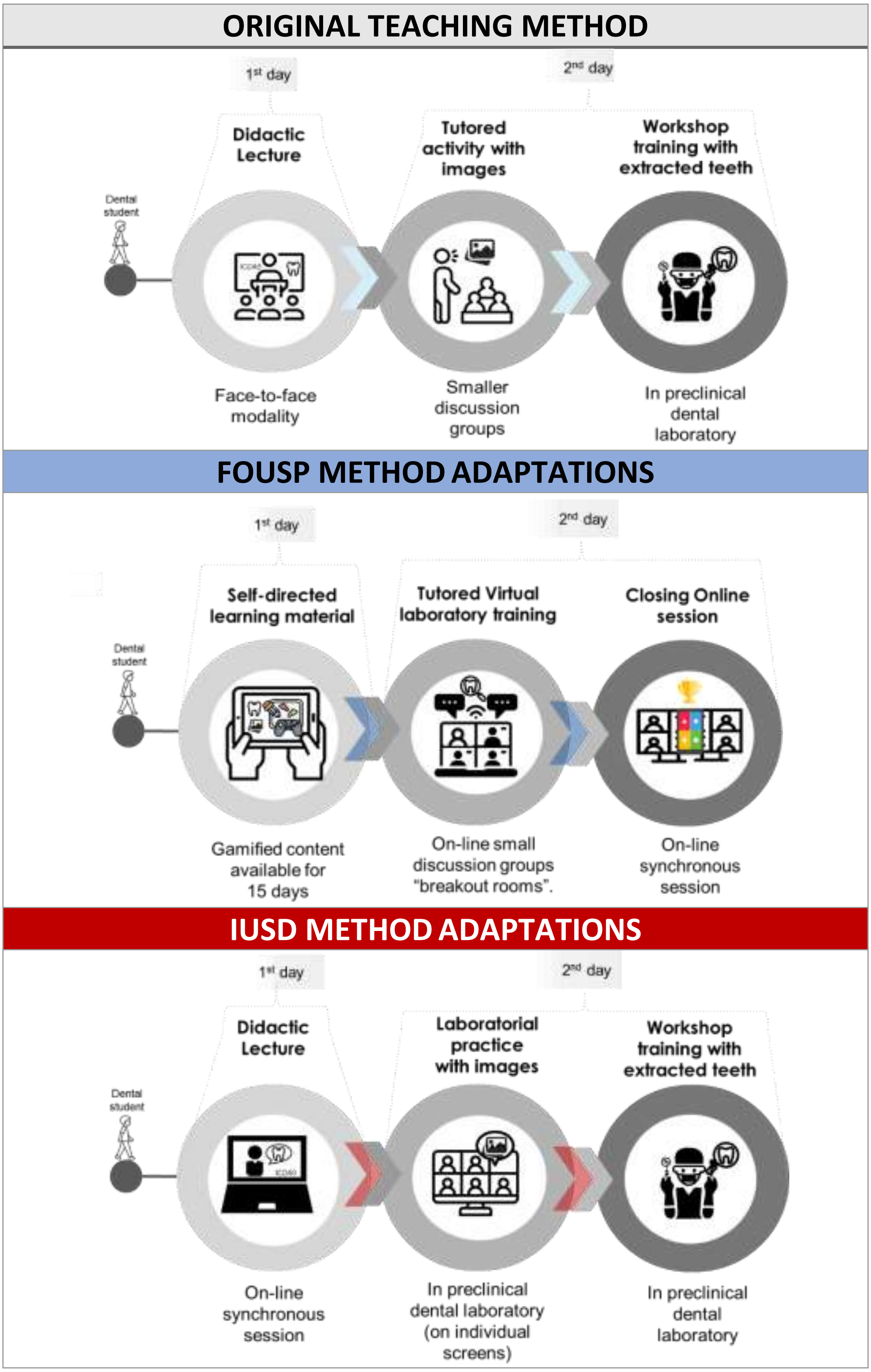
Figure 6.2 illustrates the different teaching modalities (FOUSP/IUSD) performed during the COVID-19 pandemic contrasting with the equivalent stage in the original version presented above. The following were the strategies implemented by each institution to adapt the above-mentioned teaching methodology.

THE FOUSP EXPERIENCE – DISTANCE ONLINE EDUCATION

In Brazil, on February 26, 2020, the first case of COVID-19 was confirmed in São Paulo. In March, some government actions started to be applied to prevent the spread of the infectious disease. Among them, the lockdown, instituted as a security measure for the community. Due to the emergency situation, the University of Sao Paulo authorities also decreed the suspension of all in-person activities and recommended a rapid transition to distance education.

Within that context, in the 2nd semester of 2020, the Pediatric Dentistry Department offered different distance-learning activities to 80 last-year undergraduate students. They included online classes, discussion seminars and clinical case presentations (synchronous and asynchronous). Caries detection was usually taught in one or two in-person moments comprising the didactic-practical laboratory training we have previously described, which usually lasts 1.5 hours. The initial idea was to maintain the nuances of active learning in the activities and stimulate students to engage with the content; despite the social distancing (to substitute in-person interaction with the faculty. Therefore, the lecture was reformulated and converted to a self-instructional online module, giving students even more responsibility in learning. Didactic material was prepared, in advance, by professors and postgraduate students of the department and was posted for students in a free educational platform (Google classroom), so they could study at home anytime and rehearse the contents anytime. Feedback from lecturers is also allowed on such platforms.

Figure 6.2 - Adapted methodologies compared to the original version of the teaching strategy.



Source: The author

The self-instructional material was developed, initially as a prototype, in the "Google Forms" web application (11). Some game-based headliners were used to engage the students and contribute to their active participation. The students could access them via mobile phone, tablet or computer devices anytime and several times. The gamified material was composed of three phases (Figure 6.3), each with specific learning outcomes. Every phase (A, B and C) had stages that included different paths; according to students' answers in a manner, in the end, the same lecture content would have been explored for anyone (even if they had followed different pathways). In these pathways, different resources were created for explanatory videos, flowcharts and decisions-trees, brainstorming questions, and quizzes to exploit the different topics on caries detection.

Figure 6.3 - Self-directed learning phases. All of them stimulate students to interact with the content, by offering an explanatory video (phase A), answering questions (phase B) or evaluating clinical cases (phase C)

Source: The author.

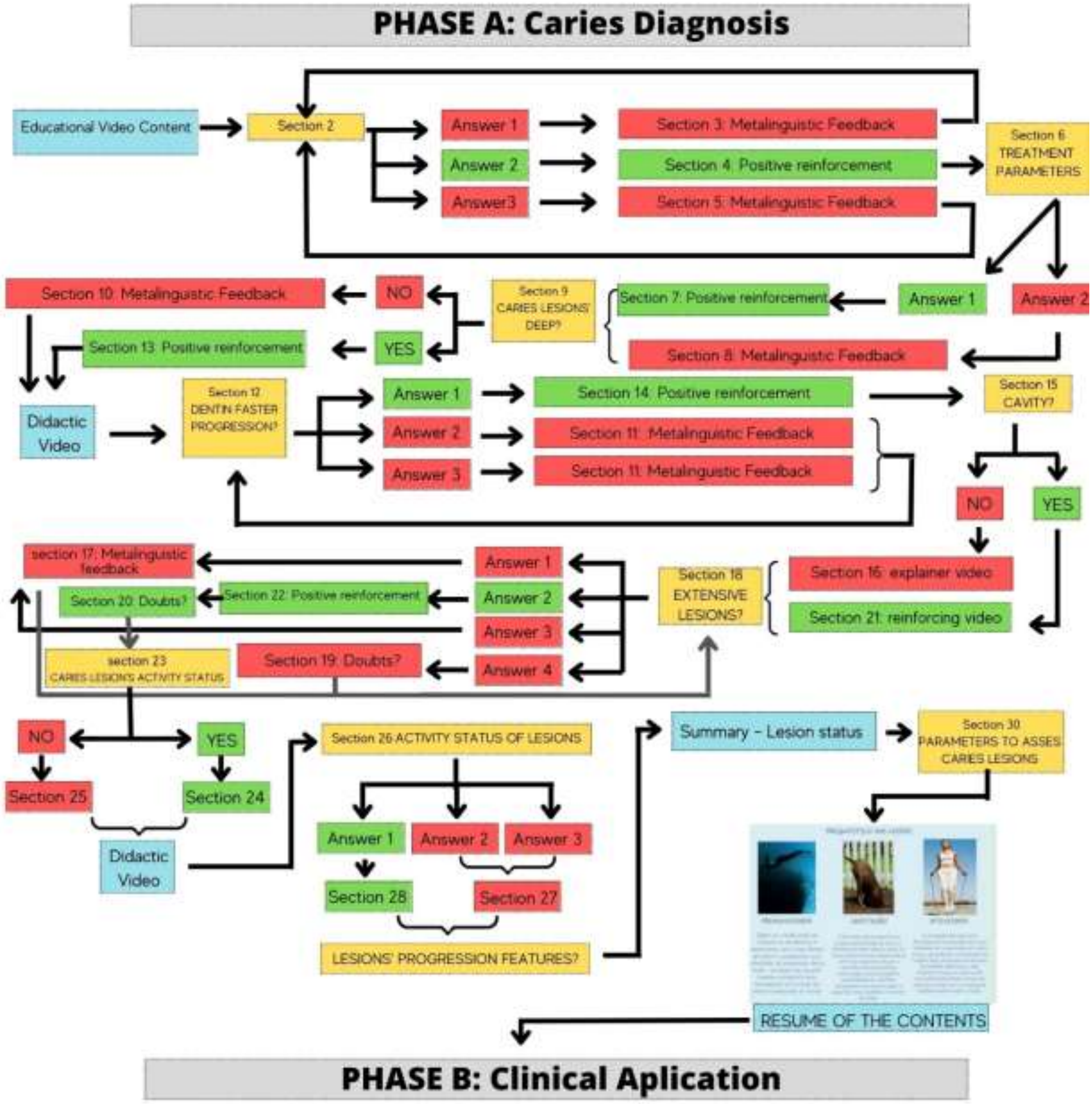
In phase "A", the student explored topics like caries diagnosis and prognosis. In phase "B", questions about caries detection in the clinical environment and concepts learned in the previous phase were asked. Finally, in phase "C", some arguments about complementary methods for caries diagnosis, effects of over diagnosing and correct management of carious lesions were broadly studied. In all the stages, students received immediate feedback about the game's different paths to help them understand why the chosen answer was correct (or not). If the student had chosen the wrong answers, they were encouraged to return to the question and answer it again. This strategy aimed not to score more points or get a higher final score but to recognize their inaccuracies and try again until they could understand the reasoning behind a particular alternative for each question (Figure 6.4). At the end of the game, it was also pointed out that the student may still need to study or learn more.

About fifteen days after the material was posted, a synchronous online session via Google Meet Platform (12) was scheduled with the class (n= 80 students). On this day, a virtual caries detection laboratory was conducted with the students. It was a continuance of the active teaching strategy, substituting the first part of the original laboratory training, performed with images. The students were divided into smaller session groups, using an innovative tool of the Google Meet platform called "breakout rooms". New virtual meeting rooms were created. Each group had about 8 to 10 dental students with at least one tutor assigned to guide the activity, using a methodology similar to the original in-person activity. The tutors were the same postgraduate students (from master's and doctorate degree programs) who collaborated in developing the self-directed learning material, so they were all calibrated.

The virtual session took 40minutes. The tutors shared in their screens images of clinical cases used in the original training and followed the same didactic strategy of in-person training. Similarly, to the original in-person activity, the tutors promoted a discussion with the students, questioning them about the severity classification of lesions according to the ICDAS and discoursing their activity status. The clinical cases and images exhibited by tutors were previously selected for this activity by professors of the discipline. Based on that images, an online game was created to stimulate active learning in this session", the Kahoot game-based learning platform was used, due to its attractive design and interactive approach (Figure 6.5) (13).

The tutors were trained to motivate students` participation and to permit that their responses were always the starting point to mediate a debate about the possible treatment options and the correct management of those lesions.

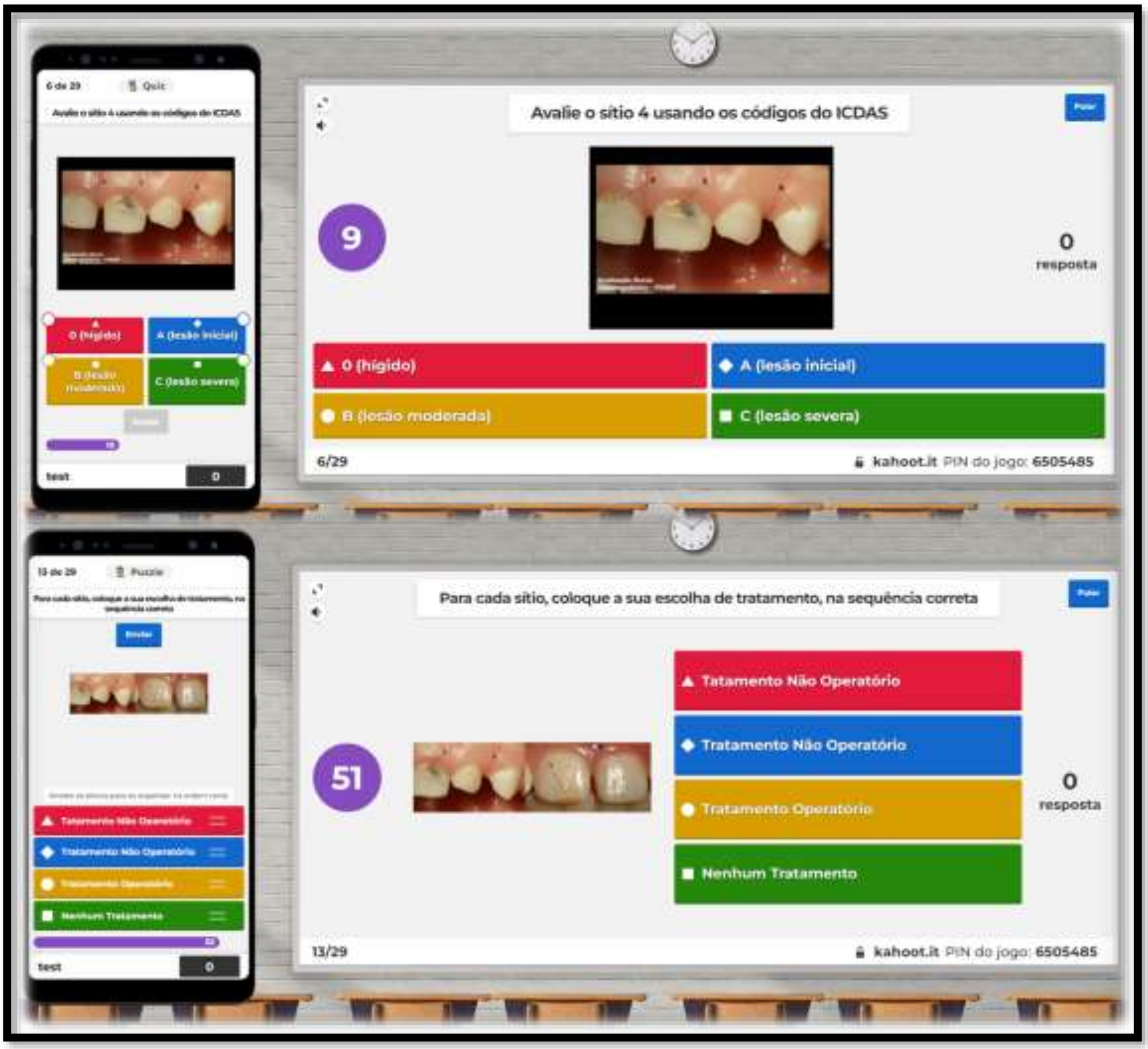
Figure 6.4 - The flowchart represents an example of the different pathways that were followed according to the students' answers in the phase A. That form and logical sequence of questions allowed students to receive immediate feedback, by clarifying their errors without explicitly providing the correct form. In that way the learner's active participation was stimulated



Source: Gently donated by Braga MM (2022).

Finally, after the small discussion groups, all students were joined in a unique virtual classroom (Google meet session) in the main conference call. A final game-based review was used to bring some closing remarks at the end of this session. The Kahoot platform was also used (Figure 6.5). This final was incentivized as a class competition where students had to answer some questions related to caries detection and to other contents delivered until that moment.

Figure 6.5 - Kahoot platform view for students. Different type of questions was used in the final class competition, such as, choice questions, true/false and matching questions



Source: The author.

As of the end of 2020, the social distance had not been terminated in São Paulo, and the stage of the practical activity using extracted teeth could not be carried out.

THE IUSD EXPERIENCE - HYBRID LEARNING MODEL

Public health agencies noted the Covid-19 cases in the United States (U.S.) between January and February 2020; however, it was declared a national emergency on March 13th. This respiratory illness was one of the leading causes of death in 2020, in the U.S., with persisting effects even in the next years. Nonetheless, at some point, with the vaccination campaign started and with the reduction in the number of new cases registered, some universities were able to return and have some in-person activities on campus. IUSD had to prepare this return and develop a complete "roadmap" (14) to slowly restart the lectures, clinics, and preclinical laboratory activities at the Dental School without neglecting the health and safety of students, patients, administrative staff and faculty members.

Faculty members from the Department of Cariology, Operative Dentistry and Dental Public Health had already planned the implementation of the IuSTC's original method for the class of 2020, as one of the sites of this multicenter research initiative. (9). However, and due to pandemic conditions, a limited number of people were allowed to be in the dental school building simultaneously, according to the rules of the IUSD biosafety committee. Therefore, they had to change the logistics and redesign how the activity would be delivered to students.

The caries detection module was offered to first-year dental students as part of the Risk Assessment, Prevention, and Early Management of Dental Disease course. A total of one hundred and five students (n=105) were exposed to the adapted methodology in IUSD. At first, an experimented lecturer gave two didactic online lectures on caries detection and ICDAS as part of their curriculum. Lectures were given by Zoom (software acquired and provided by the educational institution during the pandemic). and lasted about 60 minutes each. They were delivered to the whole class in a synchronous online session.

As part of a hybrid teaching model, the preclinical laboratories of the IUSD building were prepared to receive students after one week. Thus, the second part of this teaching strategy (a tutored practical laboratory training with images and extracted teeth) was performed in person. Given the high number of students, the training could not be carried out in the same lab for all students. To minimize the number of attendants on the same day and to maintain the recommended physical distance between students during the evaluations (6 feet), the class had to be divided into 12 smaller groups of 7, 8, or 12 students reflecting the capacity of each of the adopted lab spaces within the school facilities.

The groups were scheduled for two different weeks to receive the practical training. In the first delivery, three groups were trained simultaneously (in different laboratory spaces). Then, in a second application, on the same day, three other groups participated. After two weeks, the same methodology was performed to complete the training of the 12 groups (2 blocks of 3 groups per week). Three faculties and three graduate students participated as tutors for these practical activities besides the coordinator.

Safety protocols were adopted each week in the three different environments that students received. Temperature checking at the entrance, use of personal protective equipment (PPE), and different organization for the flow of people entering and leaving the building were implemented to avoid any contagion among the students and staff.

Fixed workstations were assigned to students at the beginning of the activity. Then, students remained in the same place until the end of the training. First, the images laboratory training was performed. For this, each student had access to a computer screen attached to their dental boxes (Figure 6.6), and the tutor discussed 30 clinical images presenting caries lesions of different severities with them. The students could interact with the professor "remotely" and solve all possible doubts about detecting and managing the lesions displayed.

For the second part of the laboratory activity, with the assessment of extracted teeth, three kits of permanent teeth (collected from the local tooth bank) were prepared as models, simulating dental arches. The teeth were selected in advance by the coordinator and exhibited caries lesions of different severities. The kits were built, maintaining the same difficulty level, sequence and proportion of surfaces to be evaluated. Before the laboratory training started each week, the models were sterilized in an autoclave and wrapped in disinfectant towelettes (CaviWipeTM) (Figure 6.7).

Figure 6.6 - The training with images was performed at the laboratory, in fixed workstations and interacting remotely

Source: The author.

The models with teeth were rotated among the students to avoid contamination. Intermediate stations were created to disinfect the model before passing it to the next student. Once the first model was evaluated, the cleaning process was undergone, and then the model was deposited in the intermediate station. Next, the subsequent student could get up and take it. In that way, there was no direct contact or interaction between students.

In the stations, each student also received a sealed envelope with the right answers for the models evaluated; they were instructed only to open the envelopes once they finished the evaluations to compare their answers as a way of feedback. One tutor (professor) was available for the respective small group of students at the lab and interacted with students only if they had doubts or questions after comparing the answers, minimizing close contact.

Figure 6.7 – Models of teeth that were prepared for the laboratorial training. After the evaluations, students must disinfect them and deposit them at the intermediate station.

Source: The author.

COST OF EDUCATIONAL INTERVENTIONS

The investment that the institutions made, per student, to teach them using an active learning framework for caries detection topic was, on average, $78 for IUSD and $64 for FOUSP.

For the completely virtual education program proposed at FOUSP, a total cost of $5091, considering a class of 80 students, was spent. The type of resource that was costliest was human resources, representing more than 90% of the total costs (Table 6.1). Given the distance learning characteristics, a minimum cost with facilities was registered (Table 6.1). In this adapted model, the cost of the development phase was much higher (almost 40 times) than delivering phase (Table 6.1).

In the IUSD training program, as they were able, since the beginning, to implement a hybrid model of teaching (online class + in-person laboratory activity), the costliest phase was the laboratory training (workshop), representing 98% of the total cost (Table 6.2). Besides, the same trend of costs' distribution was observed, having the personnel as the most expensive category (51%), followed by materials (27%) and Facilities (22%) (Table 6.2).

Table 6.1 – Costs related to the FOUSP adapted methodology, delivered completely on-line.

FOUSP	SEL-DIRECTED GAME				VIRTUAL LABORATORY				CLOSING SESSION (FEEDBACK)			
PHASES	**ASSUMPTIONS**	**TYPE OF RESOURCE**	**($) COST**	**($) COST**	**ASSUMPTIONS**	**TYPE OF RESOURCE**	**($) COST**	**($) COST**	**ASSUMPTIONS**	**TYPE OF RESOURCE**	**($) COST**	**($) COST**
DEVELOPMENT $4897.11 (96%)	Teaching staff time in elaborating videos and instructional material on digital platforms were estimated	PERSONNEL	2369.19	**2443.88**	For being a new method of teaching, tutors' calibration was necessary (performed on-line)	PERSONNEL	2450.63	**2453.23**	N/A	PERSONNEL	0.00	**0.00**
		MATERIAL	74.61			MATERIAL	2.60			MATERIAL	0.00	
		FACILITIES	0.00			FACILITIES	0.00			FACILITIES	0.00	
DELIVER $ 125.81 (3%)	No cost was registered for the institution (Asynchronous activity)	PERSONNEL	0.00	**0.00**	In smaller discussions groups an on-line quiz was performed with students	PERSONNEL	108.58	**108.70**	The lecturer was responsible for the closing session with students (final gamified quiz)	PERSONNEL	17.04	**17.11**
		MATERIAL	0.00			MATERIAL	0.12			MATERIAL	0.07	
		FACILITIES	0.00			FACILITIES	0.00			FACILITIES	0.00	
ON-LINE SUPPORT $ 68.27 (1%)	A professor was available on-line to provide feedback and solve students' problems	PERSONNEL	68.15	**68.27**	N/A	PERSONNEL		**0.00**	N/A	PERSONNEL	0.00	**0.00**
		MATERIAL	0.12			MATERIAL				MATERIAL	0.00	
		FACILITIES	0.00			FACILITIES				FACILITIES	0.00	
TOTAL COST: $ 5091 (100%)		**TOTAL**	**($) 2512.07 (49%)**			**TOTAL**	**($) 2561.93 (50%)**			**TOTAL**	**($) 17.11 (1%)**	

Source: The author

Table 6.2 - Costs related to the IUSD adapted methodology, delivered partially on-line and partially in-person.

IUSD	DIDACTIC LECTURE				WORKSHOP LAB TRAINING WITH IMAGES AND TEETH			
PHASES	**ASSUMPTIONS**	**TYPE OF RESOURCE**	**($) COST**	**($) COST**	**ASSUMPTIONS**	**TYPE OF RESOURCE**	**($)COST**	**($) COST**
DEVELOPMENT $5100 (0%)	It was already prepared , so no cost was considered	PERSONNEL	0.00	**0.00 (0%)**	It was already prepared , so no cost was considered	PERSONNEL	2496.19	**5100.47 (63%)**
		MATERIAL	0.00			MATERIAL	1057.09	
		FACILITIES	0.00			FACILITIES	1547.19	
DELIVER $3109 (100%)	The use of educational platforms and lecturer and computer technician´s time was considered	PERSONNEL	154.14	**155.43 (100%)**	The in-person activity was performed in two phases (discussion with images and assessment of teeth`s models)	PERSONNEL	1565.36	**2953.35 (36%)**
		MATERIAL	0.00			MATERIAL	1146.97	
		FACILITIES	1.29			FACILITIES	241.03	
ON-LINE SUPPORT $0 (0%)	N/A	PERSONNEL	0.00	**0.00 (0%)**	N/A	PERSONNEL	0.00	**0.00 (0%)**
		MATERIAL	0.00			MATERIAL	0.00	
		FACILITIES	0.00			FACILITIES	0.00	
TOTAL COST: $8209 (100%)		**TOTAL**		**($) 155.43 (2%)**		**TOTAL**		**($) 8053.83 (98 %)**

Source: The author.

6.4 DISCUSSION

Certainly, the COVID-19 pandemic significantly impacted education and drastically changed how dental schools were functioning (15). However, that emergency also allowed us to reinvent ourselves by stepping out of our comfort zone and embracing new experiences or perspectives. In that context, a recent systematic review discussed the changeover aspects of medical education during the pandemic, and pointed out the importance of sharing our different teaching experiences and analyzing our methods (16).

From that perspective, the main objective of this paper was to raise some relevant aspects of cariology teaching strategies performed during the pandemic and their relationship with economic outcomes. Through this report, we identified areas where we can improve as educators. By sharing those results, other institutions can also be benefited and implement changes to achieve better learning goals.

Thinking in undergraduate dental education, the student needs to acquire many practical skills that cannot be learned directly in the clinic. So, preclinical laboratory activities always seemed to be a good option. Caries detection is a topic that will be used in all disciplines as a basis of knowledge (17). Due to that, the methods used to teach students must be well-designed (18). In that line, since 2009 a Brazilian institution (FOUSP) proposed a teaching method for caries detection instruction (9) that incorporates a range of active learning techniques, primarily promoting critical thinking and problem solving skills. The original teaching method was being effectively used in several universities (as part of IuSTC-01 Trial). In 2020, due to the pandemic, some aspects had to be transformed to permit teaching students about caries detection, without losing the quality of education, since such competencies are very important for any professional in the current century (19).

In the past, distance education resources were used just as support for face-to-face activities. Currently, the pandemic has increased their application (7). There was a belief that online activities or distance learning could have a less positive effect than in-person education, but previous studies demonstrated that it could not be true (20).

The FOUSP and the IUSD schools maintained the original method's basis but implemented particular solutions to the challenges of such a moment. The institutions created resources according to the moment they were experiencing, considering the local and students' characteristics. For example, in the FOUSP, instead of having conventional distance online classes (passive learning), it was decided to include innovative educational resources, like self-directed learning and gamification. This strategy usually engages students better (21) and could minimize concerns with the reduced interaction with students at that moment of the pandemic. Indeed, many students did not turn on their cameras or microphones for several personal and technical reasons (22). Some studies have shown, however, the interaction between student-instructor tends to be better in informal channels than in online platforms, for example (23). Those aspects motivated the faculties to innovate even in the more traditional stage of educational learning, the initial lecture.

The self-directed learning material provided gave students greater autonomy over their learning experience. Students' critical thinking was stimulated since they were supposed to choose their pathways, and different answers could direct them to different pathways. Moreover, this material has a special part regarding decision-making. This inclusion was motivated since, in previous studies conducted by our research group (24,25), one of the main difficulties of students regarding caries detection is to link that to the decision-making process. As discussed in Chapter 2, students can often score the severity of caries lesions correctly but do not link such information with the management options (i.e. operative or non-operative). Therefore, when the teaching staff was developing the self-directed learning material for students, this aspect was broadly explored to improve some deficits the original learning activity had left on some learning outcomes.

As exposed before, the different pathways that students used in the self-directed learning material were very important for the engagement of the students and for helping them to learn from their mistakes. They can return to the beginning of the game at any moment and (to fail and restart) allows students to experiment without fear and increases student engagement (26). Other studies in the literature showed, as well, positive results of online feedback provided (27). Reflective practice involves actively analyzing your experiences and actions to help yourself improve and develop.

On the other hand, at IUSD, the major concerns were related to the physical structure of the building, the people flow, and the safety protocols, so the adaptations were made according to the capacity of the dental school's laboratories. Differently, from the first example, the students could return earlier to the university for in-person laboratory activities. Therefore, a more approximate format from the original version could be reached.

The different organization was devised to allow students to carry out the activities respecting the minimum distance between them and that there would be no direct interaction with either colleagues or tutors. At the time of the evaluation, the students were fully attired, with a mask, glove, lab coat, eye protection and face shield. They were assigned to a specific box and could not move. The students were required to use illumination from dental equipment to simulate a clinical scenario, during the assessment of teeth. Besides, advice was given to avoid aerosols emission when using the air/water syringe.

Although much of the images and slides used in the new instructional material were created in advance for its use in previous face-to-face lectures, the whole material had to be improved and adapted for online delivery. Other graphical material and videos were prepared to be included in such a package. Besides, the complete structure of a game should be designed and computationally developed. Consequently, that process demanded significant time and effort from the teaching staff and directly impacted the final cost of the strategy. Human resources were the most expensive component for the development and delivery phases, as observed in previous studies (28). Specifically, in the case of IUSD, delivering the training several times for different groups had an important influence on the final cost because all resources were spent several times.

Due to the sanitary conditions at that time, continuing to teach students with good quality during the pandemic was possible, even with some barriers and limitations. That was only possible because of the commitment of faculties and staff of educational institutions that worked to implement new teaching mechanisms and to use new tools for training the students. We highlight that these educational interventions were created empirically and rapidly, given urgent conditions imposed by the pandemic. Therefore, it was not worth catching up on some details. Adaptations represent a good starting point for developing more realistic and engaging teaching strategies for dental education in the future, maybe also using other improved tools, such as immersive applications or realistic games for caries detection. Besides, evaluating the economic feasibility of the new teaching methods and understanding their real cost-effectiveness is crucial since they actually represent an economic investment, as stated before.

Both institutions presented positive results in performing adapted methodologies during the pandemic. Pandemic adaptations to the teaching-learning activities on caries detection require some creativity and investment to overcome challenges represented opportunities to reinvent teaching methods and enhance the quality of education, but they may produce relevant innovations potentially to be incorporated on the routine basis

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7 FINAL CONSIDERATIONS

Several relevant issues have been discussed until now. We can highlight among them: the comparison of different methods of teaching in undergraduate dental education; the process of implementing and executing large-scale multicentre studies (with all the challenges that they represent); the importance of collaborative research to achieve educational outcomes; the use of economic evaluations within educational interventions to understand the real benefits of alternative teaching methods, even for distance learning (as in the pandemic period). We expected they can have contributed to elucidate some issues related to these matters and stimulate the execution of more research in this important field.

Assessing the impact of teaching interventions on student learning outcomes seems crucial to provide students with a high-quality education that prepares them for academic success and future clinic. The multicenter study presented in this thesis brought evidence about an alternative teaching method in Cariology that uses the active learning basis to promote an improvement in students' practical abilities for caries detection associated with favorable and efficient resource allocation.

By implementing this method, in different contexts and educational environments, as part of the IuSTC01 multicentre randomized trial, it was perceived that several challenges can be faced and that researchers must ensure that they have careful planning and adequate resources to carry out the study effectively. Interesting solutions may also be created to overcome eventual challenges and motivate the implementation partners to continue and disseminate the strategy delivery.

Also, we have to mention that the pandemic has brought significant changes and dares for dental education worldwide. However, adaptations to this unfortunate condition also bring out important contributions, especially in how dental education is delivered and may be perpetuated regularly. Some of our experiences were shared in this report.

Based on those findings exposed and discussed in this thesis, we can conclude that the tutored active-learning method, involving preclinical theoretical-practical training, significantly improved students' outcomes and was also proven cost-effective, feasible and adaptable from the educational decision-makers' perspective. Therefore, it may be considered a promising option for educational institutions that want to ensure that their students receive the best education possible regarding the development of caries detection competency while optimizing their resources and allocating them more efficiently.

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[1] De acordo com o Estilo Vancouver.

ANNEX 1- Etichc's Commitee Authorization

FACULDADE DE ODONTOLOGIA DA UNIVERSIDADE DE SÃO

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Impacto do treinamento teórico-laboratorial mediado por tutores no desenvolvimento de habilidades de alunos de graduação para detecção de lesões de cárie: estudo controlado e randomizado

Pesquisador: Mariana Minatel Braga

Área Temática:

Versão: 1

CAAE: 39632614.0.0000.0075

Instituição Proponente: Universidade de Sao Paulo

Patrocinador Principal: Universidade de Sao Paulo
UNIVERSIDADE DE SAO PAULO
MINISTERIO DA CIENCIA, TECNOLOGIA E INOVACAO

DADOS DO PARECER

Número do Parecer: 919.071

Data da Relatoria: 16/12/2014

Apresentação do Projeto:

Este estudo tem por objetivo avaliar o impacto da implementacao do treinamento teorico-laboratorial monitorado e mediado por tutores no ensino e treinamento para deteccao de lesoes de carie entre alunos de graduacao de diferentes universidades quando comparado ao metodo de ensino convencional baseado em aulas teoricas expositivas. O impacto dessa atividade de ensino-aprendizagem sera medido pela efetividade, custo- efetividade, retencao de conhecimento/competencias adquiridos e aceitabilidade da atividade pelos alunos de graduacao. Para isso, nove faculdades de odontologia estao envolvidos na inclusao de sujeitos de pesquisa. Sera conduzido um estudo controlado randomizado de grupos paralelos, no qual um dos grupos recebera apenas a aula teorica convencional, com duracao entre 60 e 90 minutos e o outro, recebera a mesma aula teorica e tambem um treinamento teorico-laboratorial com uma hora e meia de duracao, envolvendo exercicios e discussoes baseadas na avaliacao de imagens pre-selecionadas e em exame de dentes extraidos. Os desfechos acima serao avaliados imediatamente apos a atividade didatica e tambem em medio e longo prazo. Para comparar os desfechos de longo prazo, serao coletados dados de alunos formados em turmas que nao passaram pela experiencia

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de treinamento, caracterizando uma etapa de estudo nao randomizada, aninhada no estudo principal. Paralelamente, serao realizadas entrevistas com professores e alunos cursando diferentes anos do curso de graduacao de ambos os centros com o intuito de analisar qualitativamente os conteudos curriculares relacionados a Cariologia aos quais os alunos avaliados foram expostos. Esses dados serao utilizados na interpretacao dos dados coletados como desfechos. Analises estatisticas apropriadas serao realizadas para responder as perguntas inicialmente propostas pelo estudo.

Objetivo da Pesquisa:

Objetivo Primario:

Avaliar o impacto da implementacao do treinamento teorico-laboratorial monitorado no ensino e treinamento para deteccao de lesoes de carie entre alunos de graduacao quando comparado ao metodo de ensino convencional baseado em aulas teoricas expositivas.

Objetivo Secundario:

- comparar a efetividade e a relacao custo-efetividade imediato da implementacao do metodo de treinamento teorico-laboratorial monitorado com a aula teorica convencional isolada. Para a efetividade, entende-se como efeito esperado a aquisicao de conhecimento, mas tambem a de competencias teoricas, praticas e clinicas que ele apresente imediatamente apos o processo de ensino-aprendizado ao qual foi submetido; - comparar dos metodos de ensino acima mencionadas na percepcao e aceitabilidade dos alunos quando expostos as mesmas; - verificar, em medio e longo prazo, a retencao do conhecimento e das competencias adquiridos apos o treinamento teorico-pratico entre os alunos expostos a esse metodo de ensino-aprendizagem, bem como a aplicacao em sua pratica clinica apos formado e compara-lo ao de alunos de turmas nao expostas a esse tipo de treinamento, mas da mesma instituicao.- verificar a custo-efetividade do uso do treinamento laboratorial a longo prazo, levando em consideracao a retencao do conhecimento e aplicacao clinica- identificar fatores cognitivos e/ou da postura do aluno que possam estar associados a aquisicao de conhecimentos e competencias por meio da atividade pratica complementar implementada, bem como a retencao de conhecimento/competencias em longo prazo e aplicabilidade em sua pratica clinica.- comparar a efetividade e aplicabilidade das tecnicas em diferentes contextos explorados, considerando o centro coordenador, como precursor no desenvolvimento dessa atividade e a instituicao mexicana, como aquela que recebera a possibilidade de aplicacao dessa nova proposta e a tornara exequivel dentro de sua realidade.

Avaliação dos Riscos e Benefícios:

Os dados coletados serao parte das atividades didaticas normalmente desenvolvidas no curso de graduacao. Eles nao serao obrigados a participar da pesquisa e apenas entregarao os formularios de avaliacao, se consentirem com a participacao. Nao havera prejuizo na avaliacao desse aluno da disciplina, caso nao queira participar e isso sera garantido pela nao necessidade de identificacao do aluno durante todo o estudo. Mesmo sendo um estudo randomizado controlado, o grupo controle, que teoricamente nao receberia a atividade "experimental"sera exposto, apos a coleta de dados, a mesma, para que nao haja prejuizos em sua formacao. Assim, ele estara exposto aos mesmos conteudos e dinamicas que os alunos pertencentes ao grupo teste.

eneficios:

Os alunos participantes do estudo terao o beneficio de vivenciarem uma metodologia adicional em deteccao de lesoes de carie, que aumenta a exposicao do mesmo ao tema e ainda, permite a pratica desse conteudo. Alem disso, como beneficio indireto, antevemos a possibilidade de se testar se a implementacao de uma metodologia pratica no ensino desse assunto poderia contribuir para a formacao do profissional na area de Odontologia.

Comentários e Considerações sobre a Pesquisa:

A pesquisa é interessante, pioneira e deve ser incentivada.

Considerações sobre os Termos de apresentação obrigatória:

Todos os documentos necessários foram entregues.

Recomendações:

Tendo em vista a legislação vigente, devem ser encaminhados ao CEP-FOUSP relatórios parciais anuais referentes ao andamento da pesquisa e relatório final, utilizando-se da opção "Enviar Notificação" (descrita no Manual "Submeter Notificação", disponível na Central de Suporte - canto superior direito do site www.saude.gov.br/plataformabrasil).

Qualquer alteração no projeto original deve ser apresentada "emenda" a este CEP, de forma objetiva e com justificativas para nova apreciação.

Conclusões ou Pendências e Lista de Inadequações:

Não há pendências.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

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SAO PAULO, 17 de Dezembro de 2014

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