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ORIGINAL

Implementation of a Mini Maker Lab for the Creation of 3D-Printed Open Educational Resources in Dentistry

Implementación de un Mini Laboratorio Maker para la Generación de Recursos Educativos Abiertos Impresos 3D en Odontología

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ABSTRACT

This article reports the design, implementation, and preliminary evaluation of a 3D-printing maker mini-laboratory at the Facultad de Estudios Superiores Zaragoza (FES Zaragoza) of the Universidad Nacional Autónoma de México (UNAM), aimed at generating Open Educational Resources in 3D format (OER 3D) from computed tomography images of real patients. The proposal is grounded in Maker Pedagogy, Design Thinking, and the UNESCO Open Educational Movement. Three-dimensional biomodels generated by processing DICOM files using segmentation software (3D Slicer, Blue Sky Plan) and printed with FDM and SLA technologies were incorporated into active-learning activities with first- and third-year dental students. Results show a perceptible improvement in understanding stomatognathic system anatomy, bidimensional-to-tridimensional image correlation, integration of basic sciences with clinical practice, and the development of collaborative skills. The maker laboratory is positioned as a catalyst for pedagogical innovation with replicable potential across health-science higher education institutions.

Keywords: 3D Printing; Maker Laboratory; Open Educational Resources; Computed Tomography; Dentistry; Dental Anatomy; Comprehensive Diagnosis; Emergent Pedagogy; FES Zaragoza; UNAM.

RESUMEN

El presente artículo reporta el diseño, implementación y evaluación preliminar de un mini laboratorio maker de impresión 3D en la Facultad de Estudios Superiores Zaragoza (FES Zaragoza) de la Universidad Nacional Autónoma de México (UNAM), orientado a la generación de Recursos Educativos Abiertos 3D (REA 3D) a partir de imágenes tomográficas de pacientes reales. La propuesta se fundamenta en la Pedagogía Maker, el Design Thinking y el Movimiento Educativo Abierto promovido por la UNESCO. Los biomodelos tridimensionales generados mediante el procesamiento de archivos DICOM con software de segmentación (3D Slicer, Blue Sky Plan) e impresos con tecnologías FDM y SLA, se incorporaron a actividades de aprendizaje activo con estudiantes de primer y tercer año de la licenciatura en Cirugía Dentista. Los resultados muestran una mejora perceptible en la comprensión de la anatomía del sistema estomatognático, la correlación imagenológica bidimensional-tridimensional, la integración de las ciencias básicas con la práctica clínica, y el desarrollo de habilidades colaborativas. El laboratorio maker se posiciona como un catalizador de innovación pedagógica con potencial replicable en instituciones de educación superior en ciencias de la salud.

Palabras clave: Impresión 3D; Laboratorio Maker; Recursos Educativos Abiertos; Tomografía Computarizada; Odontología; Anatomía Dental; Diagnóstico Integral; Pedagogía Emergente; FES Zaragoza; UNAM.

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INTRODUCTION

The training of dental surgeons has historically relied on a pedagogical sequence that separates basic sciences from clinical practice, creating a persistent gap between theoretical knowledge—anatomy, histology, and pathology—and its application in diagnosis and treatment planning. This gap widens when students, trained using standardized models and conventional two-dimensional radiographs, encounter patients in clinical practice with real pathologies, anatomical variations, and imaging complexities that no textbook can faithfully reproduce.[1,2]

Cone-beam computed tomography (CBCT) has transformed diagnosis and treatment planning in dentistry by providing three-dimensional volumetric reconstruction of the craniofacial complex, revolutionizing fields such as oral and maxillofacial surgery, endodontics—for the localization of accessory canals and anatomical aberrations—and periodontics—for the assessment of bone density and implantology. However, its educational potential remains underutilized in most curricula.[3,4]

In this context, 3D printing emerges as a technology with high educational potential. The transformation of DICOM data from CT scans into printed physical biomodels allows the three-dimensional complexity of the surgical field to be transferred to a manipulable, tangible, and replicable object. Recent studies report that compared with conventional methods, 3D models generated from real clinical cases significantly improve students' understanding of anatomy, preparation for clinical procedures, and intrinsic motivation.[5,6,7,8]

The maker movement, understood as a pedagogical philosophy centered on learning through the design, construction, and iterative modification of artifacts, offers the ideal cultural and institutional framework for integrating these technologies with systematic, training processes (Antes et al., 2020). Creating a mini maker lab in a dental school does not merely involve installing 3D printers; it involves building a community of practice where students, interns, and faculty cocreate contextualized educational resources with real diagnostic value, distributed as Open Educational Resources (OER) under Creative Commons licenses, in line with the Open Education Movement promoted by UNESCO.[9]

This article describes the design, implementation, and preliminary evaluation of a mini 3D printing maker lab at the FES Zaragoza campus of the UNAM, within the framework of the PAPIME PE202124 project, with the aim of reporting its impact on the integration of basic sciences with clinical learning, the improvement of diagnostic imaging, and treatment planning among dental students.

Study Objective

To report on the design, implementation, and learning outcomes derived from the operation of a mini 3D printing maker lab at the FES Zaragoza-UNAM, evaluating its impact on anatomical understanding, imaging correlation, basic-clinical integration, and the development of collaborative skills among students in the Bachelor of Dental Surgery program.

Theoretical Framework

The Basic-Clinical Gap in Dentistry

In most Latin American institutions, dental education is organized into two major, temporally separate blocks: basic sciences (anatomy, physiology, histology, and pathology) and clinical subjects. This segmentation creates a structural problem: students take dental anatomy without understanding its diagnostic relevance, and when they reach the clinical setting, they lack the three-dimensional mental representations necessary to interpret radiographic and tomographic images.[10]

The difficulty of visualizing three-dimensional anatomical structures from two-dimensional representations—such as conventional radiographs—constitutes one of the main obstacles in training for diagnostic imaging. First-year dental students face the task of identifying overlapping structures, distinguishing shades of tissue density, and recognizing normal versus pathological findings without having yet developed the spatial cognitive framework required for such a task.[11] By offering a manipulable volumetric representation of the same case depicted in the radiographic image, 3D biomodels act as a cognitive bridge between the two representations.

The Maker Movement and Emerging Pedagogy

The maker movement constitutes a pedagogical philosophy centered on learning through the design and fabrication of tangible or digital artifacts. Its principles—creation, iteration, sharing, autonomy, and interdisciplinarity—align with the educational demands of the 21st century: critical thinking, problem-solving, creativity, and collaborative work. In the educational sphere, spaces dedicated to this practice are called maker environments or labs, and their institutional implementation has been shown to enhance students' intrinsic motivation, self-efficacy, and deep learning.[12,13]

Emerging pedagogy, defined as the set of pedagogical approaches that have emerged around the use of information and communication technologies in education, is one of its most concrete expressions in the maker movement. According to Lira et al.[14], emerging pedagogical practices generate learning that coexists alongside institutional prescriptive practices, responding adaptively to real educational needs. In the post-COVID-19 pandemic context, maker pedagogy emerges as a particularly relevant response to the need to rebuild in-person collaborative learning environments that simultaneously leverage the digital skills developed during emergency remote education.

3D Open Educational Resources and the Open Education Movement

UNESCO defines Open Educational Resources (OER) as freely accessible teaching, learning, and research materials published under licenses that permit their use, adaptation, and distribution.[9] In the field of health sciences, 3D OERs—printed biomodels

or freely downloadable STL files—represent an emerging category with high potential for the democratization of clinical and y knowledge, especially in contexts of socioeducational inequality where access to commercial anatomical models is limited.[15]

Creative Commons (CC) licensing constitutes the legal framework that enables the distribution of the 3D OER. CC licenses define the permissions for use, adaptation, and redistribution of materials, with different combinations of attributes: attribution (BY), noncommercial use (NC), no derivatives (ND), and share alike (SA). For the biomodels generated in the project, the CC BY-NC-SA license is proposed, which allows free educational use with attribution for noncommercial purposes and with the same license retained in adaptations. STL files are distributed through institutional repositories and platforms such as Thingiverse or the NIH 3D Print Exchange.[16,17]

Cognitive Affordances of 3D Biomodels

The concept of affordance, introduced by Gibson[18] in ecological psychology, refers to the possibility for action that an object or environment offers to a subject. Applied to educational design, cognitive affordances refer to the possibilities that a teaching tool offers the learner to think about, understand, and interact with the learning object. 3D biomodels possess specific affordances that distinguish them qualitatively from conventional representations: the ability to rotate around any axis, fragmentation to explore internal structures, direct comparison with the original radiographic image, and haptic manipulation that activates perceptual–motor learning.[19] From the perspective of activity theory, biomodels act as mediating tools that transform the subject's relationship with the object of learning. The appropriation of these artifacts is neither automatic nor homogeneous—it is conditioned by cognitive, motivational, and sociocultural factors—which demand differentiated pedagogical strategies to accompany the various levels of technological appropriation.[20]

Computed Tomography as a Data Source for 3D OER

Cone-beam computed tomography (CBCT) generates images in digital imaging and communications in medicine (DICOM) format, which serve as the raw material for the creation of educational 3D biomodels. The DICOM-to-STL conversion process involves segmentation stages—the identification and isolation of anatomical structures of interest—and three-dimensional modeling using computational algorithms. Software such as 3D Slicer, Blue Sky Plan, or Materialise Mimics allows for manual, semiautomatic, or AI-assisted segmentation of the desired structures, exporting the result in stereolithography (STL) format, which is the standard for 3D printing.[21] This processing chain, known as the 3D REA pipeline, can be designed as a completely open process when open-source software is used and the resulting files are distributed under CC licenses.

METHOD

Study Type and Design

Descriptive-exploratory educational research with a mixed-methods approach, framed within the action research methodology. It is part of the PAPIME P8202124 project titled "Learning Mediated by Open 3D Digital Resources and the Integration of Knowledge from Basic Areas with the Clinical Area," developed at the FES Zaragoza, UNAM. The quantitative dimension involves recording production indicators from the maker lab and data from student perception forms using a Likert scale; the qualitative dimension relies on participant observation, open-ended interviews, and field diary analysis.

Participants

First- and third-year students in the Bachelor of Dental Surgery program at FES Zaragoza, UNAM, participated in groups of 25 to 40 people, aged 18 to 24, who were enrolled in modules on dental anatomy (first year) and stomatological medicine and pathology (third year), respectively. Social service interns acted as mediators between faculty and students, facilitating laboratory operations and the implementation of educational activities.

Figure 1. Third-year dental surgery students with a biomodel

Design of the mini maker lab

Equipment

The maker lab was set up with the following minimum viable equipment:

- FDM (Fused Deposition Modeling) 3D printers: affordable devices using PLA filaments, which allow for the production of biomodels with a layer resolution of 0,2 mm at a low cost per unit. Patented by Scott Crump in 1989, these printers operate using five essential components: a build plate, a filament spool, an extruder, a motion system, and a print head. PLA filaments, which are biodegradable thermoplastic polymers, were selected because of their low toxicity and suitability for use in enclosed educational spaces.[22]
- SLA/MSLA (stereolithography) 3D printers: high-resolution, high-detail devices used for producing biomodels with high morphological fidelity. They use standard photopolymer resin and flexible resin, which are cured by UV light. Suitable for highly complex anatomical structures with fine detail.[22]
- Computers with sufficient hardware for processing tomographic volumes (minimum 16 GB RAM, dedicated GPU for real-time visualization).
- Desktop 3D scanner for digitizing existing physical models.

Figure 2. 3D printer in the mini maker lab

Software for the REA 3D pipeline

Table 1. Software used in the REA 3D pipeline of the mini maker lab

Software	Main function	Compatibility	Cost
3D Slicer	Segmentation and visualization of DICOM images (axial, coronal, sagittal); real-time 3D reconstruction	Win/Mac/Linux	Free
Blue Sky Plan	Dentistry-oriented 3D segmentation and modeling; STL export	Win/Mac	Academic license
Meshmixer	Repair, resizing, and optimization of STL meshes	Win/Mac	Free
Blender	Advanced open-source 3D modeling, animation, and rendering	Windows/Mac/Linux	Free
UltiMaker Cura	Slicing and file preparation for FDM printing; wide printer compatibility	Win/Mac/Linux	Free
PrusaSlicer	Slicing for FDM and SLA; open source; compatible with multiple brands	Win/Mac/Linux	Free

REA 3D Pipeline: From DICOM to Printed Biomodel

The workflow for generating 3D REA models follows five sequential steps:

1. Acquisition of tomographic data: DICOM files are obtained from the CBCT scans of real patients with pathologies of educational interest (advanced caries, periodontal pockets, root remnants, impacted teeth, periapical lesions, and cysts). All patients signed informed consent forms specifying the educational use of their studies, ensuring anonymity by removing

identifying metadata in accordance with data protection regulations.[23]

2. Segmentation and 3D modeling: using 3D Slicer and Blue Sky Plans, structures of interest (jaws, hemimandibles, individual teeth, inferior alveolar nerve, maxillary sinus) are identified and isolated through semiautomatic segmentation via Hounsfield density thresholding and manual correction. The resulting model is exported in STL format.[21]

3. Mesh repair and optimization: using Meshmixer, imperfections in the STL mesh are repaired, the model scale is adjusted, and the number of polygons is optimized to reduce the printing time without sacrificing relevant diagnostic detail.

4. Slicing and preparation for printing: in UltiMaker Cura or PrusaSlicer, the following printing parameters are defined: layer resolution (0,15–0,2 mm FDM; 0,05 mm SLA), infill percentage (15,20 %), support generation, and optimal model orientation. The resulting G-code file is transferred to the printer.

5. Postprocessing and cataloging: this includes support removal, cleaning, sanding, and, for SLA models, UV curing. Each biomodel is labeled with a QR code that links to the original digital DICOM image, anonymized medical history, and educational fact sheet, thereby creating a hybrid physical-digital OER. The STL files are published under a CC BY-NC-SA license in the institutional repository.

Figure 3. Workflow for generating 3D models

Pedagogical Framework: Design Thinking and the Maker Community

The learning activities were designed following the six-stage design thinking model: understand, define, ideate, prototype, test, and refine. In the empathy stage (understand), faculty and interns interviewed students to identify their difficulties in interpreting tomographic images and their understanding of the anatomy of the stomatognathic system. In the define stage, the groups created informational cards with radiographic images and descriptions of common pathologies, building their own reference material. The ideation and prototyping stages involved advanced students in the creation of new biological models under faculty supervision and with the support of interns. The testing stage consisted of implementing the activities with first- and third-year groups, and the refinement stage incorporated participants' observations to improve the pedagogical designs in subsequent cycles.

The Maker Community was built in three progressive stages: (a) an exploratory stage, in which students interacted with preexisting biomodels to identify structures and pathologies; (b) a participatory stage, in which groups of advanced students learned to use segmentation software and participated in the creation of new models; and (c) a productive stage, in which participants designed and produced their own 3D OER, which were incorporated into the institutional repository.

Figure 4. Prototyping process, Design Thinking methodology

Data collection instruments

The following instruments were used: (a) participant observation recorded in a field journal during learning sessions with

biomodels; (b) open-ended individual and group interviews at the conclusion of each activity; (c) online forms using a Likert scale (1–5) regarding motivation, anatomical understanding, and perception of the clinical value of the biomodels; and (d) maker lab production log: number of biomodels generated, diversity of pathologies represented, and availability in the repository.

RESULTS

Maker Lab Output

Throughout the implementation period, the mini maker lab generated an initial library of 3D biomarkers that included a mandible with impacted third molars and a relationship to the inferior alveolar nerve; an upper maxilla with a periapical cyst associated with a tooth that had undergone prior endodontic treatment; a partial skull with an infratemporal fossa for teaching the temporomandibular joint (TMJ); a hemimandible with a Class III periodontal pocket; and an upper anterior segment with a root remnant and perforation of the maxillary sinus membrane. All STL files, along with anonymized DICOM images and educational handouts, are available in the institutional mini maker lab under a CC BY-NC-SA license.

The average cost per biomodel printed using FDM with PLA filaments was significantly lower than that of equivalent commercial anatomical models, which confirms the economic viability of the maker lab as a strategy for democratizing diagnostic-quality teaching resources.

Figure 5. Skull biomodel obtained from CT scan data

Impact on Anatomical Understanding and Image–Anatomy Correlations

The results of the perception forms and field observations document consistent improvements in three cognitive dimensions. First, students who interacted with the biomodels demonstrated a greater ability to locate relevant anatomical structures—such as the course of the inferior alveolar nerve, the boundaries of the maxillary sinus, and the morphology of the mandibular condyle—than did the analysis of conventional radiographic images alone. Second, a notable improvement was recorded in the two-dimensional-to-three-dimensional correlation: students were able to directly compare the on-screen tomographic image with the physical biomodel, gradually developing the spatial cognitive framework necessary for diagnostic imaging. Third, metacognitive awareness emerged in several cases, expressed in terms of "I realized that I need to know the anatomy well; I need to learn it better," a phenomenon also documented by a study as one of the most valuable pedagogical effects of 3D biomodels.

A finding of particular diagnostic relevance was the identification, through the printed physical biomodel, of a perforation of the maxillary sinus membrane that was not visible in the digital tomographic image. This discovery, with direct therapeutic implications in a real clinical context, constitutes objective evidence of the added value of physical biomarkers over digital representations alone.

Integration of Basic Sciences with Clinical Learning

Activities with 3D biomodels served as curricular bridges between basic science modules and clinical scenarios. First-year students who worked with the temporomandibular joint model reported a significantly deeper understanding of the condyle–fossa–articular disc relationship than that obtained through textbook illustrations did. In the third-year groups, biomarkers of surgical cases (impacted third molars and cysts) were used to plan oral surgery approaches with greater anatomical detail: students measured distances between the apex of the impacted tooth and the dental nerve, identified the proximity of the maxillary sinus, and anticipated potential intraoperative complications, thereby developing treatment planning skills that are typically acquired only in advanced clinical practice.

Development of Collaborative Skills and the Maker Community

The "students-teaching-students" approach, facilitated by the involvement of upperclassmen and social service interns in the laboratory's operations, fostered support networks across semesters that helped rebuild the academic community. By virtue of being recent graduates and sharing a generational closeness with the students, the interns acted as effective pedagogical mediators, contributing fresh knowledge and an empathetic disposition that fostered active participation. The testimonials collected are

consistently positive: “When will the app be uploaded to the virtual classroom so we can keep practicing?”; “Can we have models of all the pathologies in the curriculum?”; “Seeing the lesion on the model helped me understand what I read in the book.”

Figure 6. Joint activity between social service interns and third-year students

Teamwork around the biomarkers promoted collaborative differential diagnosis: students compared their observations, discussed possible pathologies, and collectively constructed a diagnostic interpretation that none of them would have reached individually. This process is consistent with the connectivist principle that learning occurs in the connections between nodes of information and with the Vygotskian perspective of the zone of proximal development activated by interaction with more expert peers.

Participants’ Perceptions

Table 2. Participants’ perceptions of activities with 3D biomarkers (Likert scale 1–5; n = 78)

Indicator	Mean	Comments
Motivation during the activity	4,7	High emotional engagement
Understanding of anatomical structures	4,5	Better than the textbook
Usefulness for treatment planning	4,6	Relevant in the 3rd year
Correlation between 2D images and 3D biomodels	4,4	Requires additional practice
Quality of collaborative teamwork	4,6	Aids in differential diagnosis
Overall assessment of the experience	4,8	Request for continuation

Note: data obtained via an online form administered at the conclusion of the biomodel work sessions. The scale ranges from 1 (very low) to 5 (very high).

DISCUSSION

The maker lab as a catalyst for curricular integration

The results support the hypothesis that the 3D-printed mini-maker lab can serve as a catalyst for curriculum integration between basic sciences and clinical dental practice. Manipulating biomodels generated from real clinical cases places the student on a continuum between abstract anatomical knowledge and concrete diagnostic reality, activating transfer processes that are rarely achieved with conventional methodologies.[8,11] This finding is consistent with the perspective of embodied cognition, which posits that knowledge is also constructed through the body and the manipulation of physical artifacts and not only through language or abstract representation.[19]

In curricular terms, the maker lab has the potential to integrate with multiple modules of the curriculum, from anatomy in the first year to oral surgery, endodontics, and implantology in advanced semesters. The progressive expansion of the biomodel library—in line with the diversity of pathologies in the curriculum—can transform the lab into a cross-disciplinary resource with an impact on the entire dental education program. This perspective is consistent with the recommendations of Seifert et al.[2] and Hu et al.[7], who document the superiority of 3D-printed models over standardized commercial models for training in specific surgical procedures.

Diagnostic affordances of biomodels: beyond teaching

A particularly significant finding was the identification of maxillary sinus membrane perforation exclusively through the physical model.[24,25,26] These findings suggest that the affordances of 3D biomodels are not limited to the pedagogical realm but may have direct diagnostic implications even for the treating clinicians themselves. In the context of contemporary dentistry, where 3D model-assisted surgical planning is already an established practice in maxillofacial surgery and implantology,[3] the university maker lab can become a hub connecting clinical research and undergraduate education, democratizing access to resources that in other contexts are exclusive to highly specialized centers.

Pedagogical role of interns: Generative mediators of knowledge

The participation of social service interns as pedagogical mediators emerged as a distinguishing feature of the proposal.[27,28] Their liminal position—as recent graduates with up-to-date knowledge and who were generationally close to the students—allowed them to act as more accessible interlocutors than tenured faculty in the transmission of technical knowledge regarding the use of software and 3D printers. This mediating function is consistent with Vygotsky's theory of the zone of proximal development: the interns represent a level of competence slightly higher than that of the students, which maximizes the effectiveness of pedagogical scaffolding. These findings have implications for the design of social service programs for health faculties, which could explicitly incorporate maker facilitation roles.[29,30]

Figure 7. Faculty participants and social service interns

Ethical and Legal Considerations

[ESCUDOS·O·LOGOS·INSTITUCIONALES] → ¶

CONSENTIMIENTO INFORMADO PARA LA PARTICIPACIÓN EN EL PROYECTO ¶
"título del proyecto"¶
¶
¶
Yo, **[nombre completo del participante]**, estudiante de la asignatura **[nombre de la asignatura]**, de la carrera **[nombre de la carrera]** en **[nombre del plantel]** acepto participar de manera voluntaria en el proyecto **[título del proyecto]** llevado a cabo por **[nombre de la persona y/o institución responsable].**¶
¶
Después de ser informado sobre el proyecto, para conocer el propósito y las implicaciones del mismo, comprendo que el objetivo es **[objetivo del proyecto]** y entiendo que mi participación consiste en **[describir tipo de participación e información].** Asimismo, comprendo que dicha información será tratada de manera **anónima y confidencial**, y que será utilizada para fines de **[usos de la información].**¶
¶
Finalmente, comprendo que no generaré gastos, no recibiré remuneración alguna y no habrá sanción alguna para mí en caso de **revocar esta autorización.** Por ello, dicha revocación puedo realizarla en cualquier momento, si lo considero conveniente a mis intereses, mediante un correo a la dirección electrónica **[correo electrónico].**¶
¶
¶
Fecha:¶
¶
¶
Nombre y firma del participante:¶
¶

Figure 8. Example of an informed consent form. Educational research project

The use of tomographic data from real patients as raw material for 3D OERs requires a rigorous ethical protocol that guarantees respect for the autonomy, privacy, and dignity of participants. Informed consent must clearly specify the educational use of the data, the anonymization measures employed, and the distribution channels for the generated resources. Anonymization must be robust: it involves the removal of all identifying metadata from the DICOM file—name, date of birth, file number, and acquisition device data—to ensure that no reidentification is reasonably possible, in accordance with GDPR regulations and equivalent national regulations.[23,24]

Study Limitations

The main limitations of this study are (a) the small size of the participating groups and the predominantly qualitative and exploratory nature of the assessment instruments, which limits the empirical robustness of the conclusions; (b) the absence of control groups that would allow for comparisons of results with conventional methodologies under controlled experimental conditions; (c) the time required to produce diagnostic-quality biomodels, which is incompatible with the usual dynamics of teaching schedules; and (d) the reliance on external institutional funding for equipment maintenance and the purchase of consumables. These limitations point to the project's future research agenda.[31,32]

CONCLUSIONS

The implementation of a mini 3D-printed maker lab at FES Zaragoza-UNAM is a pedagogical strategy with a solid theoretical foundation, demonstrated technical and economic feasibility, and promising educational outcomes for dental education in the post-COVID-19 pandemic context.

By combining clinical fidelity, tangibility, manipulability, and real diagnostic value, the 3D biological models generated from CT scans of real patients constitute teaching resources that qualitatively surpass conventional two-dimensional representations and standardized commercial anatomical models. Their integration into design thinking and maker community activities enhances students' motivation, collaboration, integration of basic and clinical knowledge, and treatment planning skills.

The distribution of biomodels as OERs under Creative Commons licenses aligns with the ethical goals of the Open Education Movement: to democratize access to high-quality diagnostic resources for institutions with limited resources, thereby helping to reduce inequality gaps in higher education in the health sciences in Mexico and Latin America.

Dental higher education institutions are encouraged to consider creating maker labs with minimal viable equipment (a PLA filament 3D printer, computers with free software, and a conventional printer for teaching materials), incorporating student interns' community service as the human driving force behind the project, and aligning its operation with the curricular objectives of multiple modules in the curriculum.

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CONFLICT OF INTEREST

None.

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