TLEF Project – Final Report

Report Completion Date: (2021/01/31)

1. PROJECT OVERVIEW

1.1. General Information

Project Title:	Understanding Congenital Heart Disease through 3D-Models		
Principal Investigator:	Shreya Moodley		
Report Submitted By:	John Jacob		
Project Initiation Date:	04/01/2020	**Project Completion Date:**	31/12/2020
Project Type:	☐ Large Transformation ☒ Small Innovation ☐ Flexible Learning ☐ Other: [please specify]		

1.2. Project Focus Areas – *Please select all the areas that describe your project.*

☒ Resource development (e.g. learning materials, media)

☐ Infrastructure development (e.g. management tools, repositories, learning spaces)

☐ Pedagogies for student learning and/or engagement (e.g. active learning)

☐ Innovative assessments (e.g. two-stage exams, student peer-assessment)

☐ Teaching roles and training (e.g. teaching practice development, TA roles)

☐ Curriculum (e.g. program development/implementation, learning communities)

☐ Student experience outside the classroom (e.g. wellbeing, social inclusion)

☐ Experiential and work-integrated learning (e.g. co-op, community service learning)

☐ Indigenous-focused curricula and ways of knowing

☐ Diversity and inclusion in teaching and learning contexts

☐ Open educational resources

☐ Other: [please specify]

1.3. Project Summary

Cadavers are the gold-standard for anatomy education. They offer a three-dimensional (3D) representation, a sense of how features feel and an appreciation of depth, fragility and variability in the human body. However, costs of obtaining and preserving cadavers, maintenance of anatomy laboratories, and ethical, legal and religious issues relating to donor bequest programs are a few challenges associated with using cadavers. Emerging technologies such as virtual reality (VR) and 3D printing have great potential as adjunct teaching tools, particularly when cadavers are scarce or the pathology is rare and complex. One pathology that can benefit is Congenital Heart Disease (CHD).

Our project aimed to redesign and implement learning materials that involve 3D technologies for the teaching of CHD, an integral component of the medical undergraduate curriculum. The multi-modal module utilized high-resolution medical images to create 3D models that accurately depict cardiac lesions of varying complexity. Artifacts were used in MEDD411, and could be used for MEDD 431, and the fourth-year senior elective course(s) in the future.

1.4. Team Members

Name	Title/Affiliation	Responsibilities/Roles
John Jacob	Senior Director and Head of Digital Lab/BC Children's Hospital	Developed the modules
Sima Zakani	Lead Engineer/ Faculty of Medicine UBC	Developed the modules
Chelsea Stunden	Manager, Research & Evaluation/ Faculty of Medicine UBC	Developed the modules and led testing and evaluation
Peter Choi	Course Co-Director MEDD 411 / Faculty of Medicine UBC	Helped to administer the modules
Karen Pinder	Course Co-Director MEDD 411/ Faculty of Medicine UBC	Helped to administer the modules
Helen Dyck	Manager / Faculty of Medicine	Helped to administer the modules
Jonathan Bush	Pediatric Pathologist / BC Children's Hospital	Helped to select cases, consulted during iterative testing
Tony Fang	Medical Student	Consulted during development and user testing

1.5. Courses Reached –

Course	Section	Academic Year	Term (Summer/Fall/Winter)
MEDD 411	Heart Murmurs	2020/21 – Ongoing	Fall
MEDD 431	Clerkship	2020/21 – Ongoing	Fall/Winter
Other senior electives	As identified	2020/21 – Ongoing	Summer/Fall/Winter

2. OUTPUTS AND/OR PRODUCTS

2.1. *Please **list** project outputs and/or products (e.g. resources, infrastructure, new courses/programs). Indicate the current location of such products and provide a URL if applicable.*

Product(s)/Achievement(s):	Location:
E-Learning Course	https://rise.articulate.com/share/eQ0FugLApO_9ApTmGJDy0WjK1SSLrcQI
3D Printed Models	Physical models are available on request for teaching
Virtual Reality Models	https://sketchfab.com/UBC.MEDVID
3D PDFs	Embedded within the e-learning course

2.2. Item(s) Not Met

All the changes below were pre-approved in consultation with Senior Associate Director, CTLT.

Item(s) Not Met:	Reason:
Learning experience changed from in-person to online	COVID-19
Integration of virtual reality changed from head mounted display to immersive video	COVID-19
3D printed models could not be handled in person, we used them in the videos instead and created virtual models for exploration	COVID-19
Evaluation design changed from a randomized clinical trial to a pre-post design	COVID-19

3. PROJECT IMPACT

3.1. Project Impact Areas – *Please select all the areas where your project made an impact.*

☒ Student learning and knowledge

☒ Student engagement and attitudes

☐ Instructional team teaching practice and satisfaction

☐ Student wellbeing, social inclusion

☐ Awareness and capacity around strategic areas (indigenous, equity and diversity)

☐ Unit operations and processes

☐ Other: [please specify]

3.2. What were you hoping to change or where were you hoping to see an impact with this project?

During this project, we intended to transform the learning experience for undergraduate medical students by implementing 3D models for 6 select CHD pathologies to teaching and learning curriculums. Use of this innovative technology resulted in sustainable benefits to students, that were evidenced by our evaluation. The module intended to:

- Improve retention of the intended learning outcomes, which included: 1) Learning the anatomical features of a normal heart; 2) Understanding the spatial arrangements of anatomic features and physiology of CHD; 3) Incorporating this knowledge into clinical contexts
- Enhance the undergraduate student experience by offering every student the opportunity for active learning experiences with 3D models.
- Improve utility and access to sustainable resources for instructors and students, as 3D technologies can be used virtually anywhere inside or outside the classroom.
- Alleviate the reported challenges with using cadaveric specimens (e.g. reducing costs and availability restrictions associated with sourcing and preserving; reducing wear and tear due to handling).
- Improve engagement with students by introducing novel new technologies and stimulating interest for innovation in health care.

Our project remained overall quite similar in scope to the original proposal, and retained our goal of redesigning and implementing innovative learning materials that leverage 3D technologies; however because of the COVID-19 situation, as opposed to emphasizing impacts within the delivery of face-to-face learning labs, our adapted approach focused on developing an eLearning module that integrates digital 3D models that can be distributed at scale to learners attending virtual sessions. The product created with this approach will have a lasting impact beyond the current circumstance, and in fact, broadens the accessibility and reach of the resources that were created. The sections below provide a high-level summary of our adapted approach:

1. *Learning Experience*

ORIGINAL: The curriculum for the MEDD 411 Foundations of Medical Practice involves teaching the clinical presentations of congenital heart defects, which are explored through case-based presentations in small group sessions, lectures, labs, self-directed learning activities and clinical experiences. The small groups sessions are facilitated with over 190 students per year, and include a two-hour session where students have the opportunity to explore six cadaveric hearts with congenital defects. Students are divided into paired groups and alternate between 2 rooms, each with 3 hearts. Originally, these sessions were to be supplemented with the use of additional non-cadaveric 3D-printed models to increase accessibility.

ADAPTATION: The curriculum for the MEDD 411 Foundations of Medical Practice remained the same, but was adapted to include a multimedia e-learning module that could be facilitated with all 190+ students per year. The module offered students the opportunity to learn about the same six congenital heart defects, and explore them virtually using digital 3D technologies (integrated into the digital learning experience). Modules contained learning checks to test the students understanding of the learning objectives. The module was delivered as an adjunct to supplementary information delivered through Zoom learning.

2. *3D Technologies and Printed Models*

ORIGINAL: The original plan involved the development of 3D printed cardiac models, as an adjunct to cadaveric models in the small group sessions with MED411 students.

ADAPTATION: The replicate models of the congenital heart diseases were crafted using advanced 3D printing technologies. As opposed to primary use in-person, the 3D models were featured within the e-learning modules. The printed models are available for use once the pandemic is over, and discussions have emerged to explore whether we can make these available as future library resources.

3. *Integration of Virtual Reality*

ORIGINAL: The original plan was to create virtual reality models that allowed users to explore, learn, and visualize cardiac anomalies in a virtual or augmented reality environment during the small group sessions.

ADAPTATION: Given the uncertainty of in-class and large group gatherings, the use of in-class virtual reality was not a feasible plan. Instead, 3D virtual models were embedded within the learning modules that can be used at-home with simple and easily accessible software. In some cases, if students have appropriate equipment at-home, they may be able to access and view these models in virtual reality.

4. *Evaluation Design*

ORIGINAL: Our original evaluation included conducting a randomized clinical trial (RCT) to test the effectiveness of the 3D models in MEDD 411. The study design involved randomly assigning to one-of-two groups: 3D models + cadavers (experimental group), or cadavers only (control group).

ADAPTATION: Given the uncertainty of being able to conduct in-person sessions, we implemented the new e-learning pedagogy with all undergraduate medical students and evaluated the experience with the same metrics originally provided, but under a single group pre-/post- study design.

3.3. Were these changes/impacts achieved? How do you know they occurred?

The e-learning modules was evaluated using iterative feedback from potential knowledge users and experts, including designers, clinical faculty, medical students, medical residents, and a cardiac nurse. Once the e-learning course was created, it was evaluated prospectively within the Fall MEDD 411 cohort of students and instructors (N=190) in October 2020. MEDD 411 was selected for the evaluation since they were the primary cohort interested in implementing the e-learning module, but we are anticipating use of the learning materials with other undergraduate medical courses (MEDD 431 and senior elective courses). The evaluation sought to further determine (in conjunction with results from alpha testing) whether the course met the needs of users in ways that will led to sustained adoption and produced maximum impact on learning.

Each student was invited to complete 3 questionnaires throughout the evaluation (pre-test, post-test, usability). Questionnaires were administered online via Qualtrics and completed remotely and concurrently within the course. In order to improve compliance, we arranged the course so that learning check questions had to be completed before moving onto subsequent sections of the course. We also introduced an opportunity to enter into a draw for one of three Amazon gift cards, with the chance to enter after completing the usability survey. The analysis provides insights on where efforts should be placed in future development of the e-learning.

The protocol for administering the evaluation was as follows:

1. Students were given an electronic informed consent form prior to completing the e-learning course. Students who do not indicate consent could continue without completing the evaluation components.
2. The pre-test was administered online (5-10 minutes). The pre-test was used to evaluate the student's basic knowledge about CHDs prior to completing the e-learning course, and included 10 questions to assess learning objectives through multiple choice questions, true/false questions, fill-in-the-blank, and matching questions.

3. The e-learning modules were estimated to be completed in 2 hours based on our user testing prior to release.
4. The post-test was administered online (5-10 minutes). The post-test was used to evaluate the student's knowledge about CHDs after completing the e-learning course. The format mirrored the pre-test, using 10 questions to assess learning objectives through multiple choice, true/false questions, fill-in-the-blank, and matching questions.
5. Participants were then asked complete a usability questionnaire adapted from the literature (Zaharias & Poylymenakou, 2009). The usability was also administered online (5 minutes).

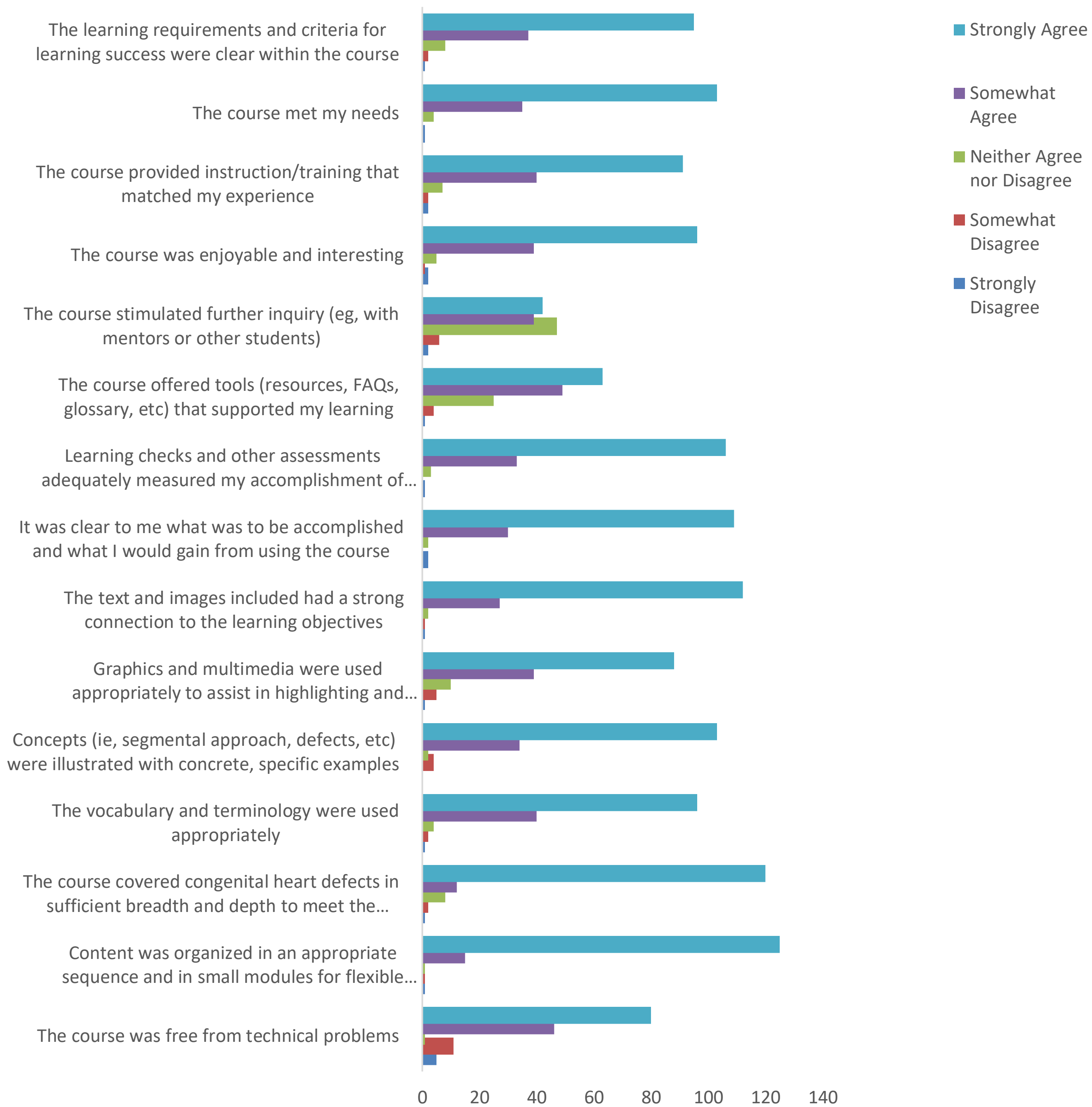
Acquired knowledge about congenital heart defects: A pedagogic evaluation of learning outcomes was conducted and is in accordance with methods for evaluating knowledge retention described by other investigators in the literature (de Faria et al., 2016; Loke et al., 2017; Peterson & Mlynarczyk, 2016; White et al., 2018). To address prior knowledge about CHDs, students were asked to name the anatomical features of a normal heart, the spatial arrangements of anatomic features and physiology of congenital heart defects, and apply the knowledge into clinical contexts described in the modules. To address knowledge after the e-learning module, students were again asked to name the anatomical features of a normal heart, the spatial arrangements of anatomic features and physiology of congenital heart defects, and apply the knowledge into clinical contexts described in the modules. Students were able to score 0-10, depending on how many structures they properly indicated. Testing results were calculated as the proportion of correctly answered items and were analyzed within the Qualtrics software. The change in assessment scores were used to compare learning outcomes between groups. We administered a two-tailed t-test to test for the statistical significance between pre- and post-test scores. Students' knowledge significantly improved by an average of 44.6% between tests (SD 1.73, $Z = -10.287$, $p < 0.001$). The median score for the pre-test was 50% (IQR 20%) and the median score for the post-test was 100% (IQR 10%).

Test Scores

Field	Minimum	Maximum	Median	IQR	Count
Pre-Test Score	1.00	10.00	5.0	2.0	141
Post-Test Score	7.00	10.00	10.0	1.0	141

Positive attitudes and experiences: A usability questionnaire was adapted from the literature (Zaharias & Poylymenakou, 2009). The results of the usability questionnaire were calculated using descriptive statistics, analyzed in the Qualtrics software. Other methods typically used for evaluation, such as live interactions involving students interacting with the product or comparison groups, were not feasible to facilitate because of the COVID-19 pandemic. Overall students exhibited positive attitudes and experiences with the course.

Attitudes and experiences with the e-learning modules.



3.4. Dissemination

- We are exploring the possibility of submitting a manuscript for publication (Journal TBD).

4. TEACHING PRACTICES

Teaching anatomy is fundamental for medical education. The COVID-19 pandemic has had enormous effects on anatomy education. During the pandemic, undergraduate students had limited (if any) access to cadavers, which has been the principle way of learning anatomy within the Faculty of Medicine. In the absence of in-person classrooms, the e-learning module provided a systematic method of delivering course content, in addition to supplementary information, instead of using alternative methods such as Zoom calls (which was the status quo at this time). As well, we report improved experiences through meaningful incorporation of novel teaching and learning materials. Evidence suggests that effective pedagogy leads to academic achievement, social and emotional development, acquisition of technical skills, and a general ability to contribute more. Given the positive review of these technologies, it is likely that they will continue to be used as supplements to in-person instruction. As the instructors apply these new skills in their respective cohorts, about 550 students will be reached per year. Over the next five years, this translates to at least 2,750 students who will benefit from enriched learning experiences.

5. PROJECT SUSTAINMENT

We are exploring options for funding to expand learning with 3D technologies to other clinical areas and learning levels. We foresee other options for transformational learning with 3D technologies that can support student learning, especially during the COVID-19 pandemic. We anticipate this e-learning course in congenital heart diseases will be expanded for use with advanced learners. We have also recently received funding to create new learning opportunities for medical students (including a virtual surgical suite for training medical students for operating room procedures). The challenges with using technology to support learning include the rapid and ongoing advancements, as well as potential changes in clinical guidelines that will need to be reviewed and updated every 2-5 years. However, the course has been embedded on an established technology infrastructure and software platform (Rise Articulate 360) that will make new course components easy to create and simple to maintain.