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Impact of an E-Learning Histology Course on the Satisfaction and Performance of Medical, Nursing and Midwifery Students

Impacto de un Curso E-Learning de Histología en la Satisfacción y Desempeño de Estudiantes de Medicina, Enfermería y Obstetricia

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SUMMARY: The importance and relevance of e-learning courses in medicine and health sciences has increased significantly in the last decade. Despite this, there are few published teaching experiences of e-learning histology courses in the literature worldwide. The histology course we designed was structured on the Moodle platform as a learning management system, and the content was proposed in a synchronous (zoom) and asynchronous (recordings) format. We also included the use of free virtual microscopy tools. This study aimed to investigate the impact of an e-learning histology course on the satisfaction and performance of medical, nursing and midwifery students. The sample included 424 Chilean medical, nursing, and midwifery students from two cohorts. A Likert-type survey was administered at the end of the course. We performed exploratory analysis and ordinary least squares regression. In this study, we present a positive experience of an e- learning histology course. Exploratory factor analysis revealed three main factors related to "e-learning satisfaction", "in-person class activities", and "course design and teaching quality". We also found that there was a positive and significant relationship between students' perceptions of the adaptation of the traditional (face-to-face) histology course into an e-learning format and their academic performance. Our study shows that e-learning histology courses that integrate lectures and practical sessions can be a valuable teaching method for learning histology. Curriculum developers and teachers need to consider the limitations and advantages of this type of teaching and incorporate these three factors into the design and assessment of e-learning histology courses.

KEY WORDS: Medical education; Health professions education; E-learning; Histology course; Student satisfaction.

INTRODUCTION

The importance and relevance of e-learning courses in the field of medicine and health sciences has increased significantly in the last decade. The majority of experiences documented in the literature are positive (Barbeau *et al*., 2013; Lavender *et al*., 2013; Antonoff *et al*., 2014; Arbour *et al*., 2015; Jayakumar *et al*., 2015; Srinivasan, 2020; Wilhelm *et al*., 2022) however, there is a lack of published teaching experiences related to e-learning histology courses in the global literature (Barbeau *et al*., 2013; Darici *et al*., 2021).

In an e-learning course, the entire subject matter or educational program is delivered through the virtual classroom. This includes the study of disciplinary content, schedules and deadlines for assignments, assessment tools, and all types of interaction that take place in the virtual environment (Zhao *et al*., 2015). Two types of activities facilitate this interaction: synchronous and asynchronous. Synchronous activities involve interactions between students and teachers using the platform in real time (Srinivasan, 2020). Live lessons, video calls, chats,

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assignments, assessments, and various other types of interactions can take place, with the main benefit being the provision of immediate feedback from the teacher. Students can also collaborate by working together in group activities. Asynchronous activities involve the delivery of content in the form of lessons, activities, or assessments that students can complete independently, with delayed or predefined dates and times set by the instructor. Some of the described benefits of e-learning courses are that it allows students to study subjects despite geographical challenges such as long distances (Bell & Federman, 2013). In addition, it provides easy and user-friendly access to study materials through platforms such as Moodle and Canvas (Godoy-Guzman *et al*., 2019). It also allows students to manage their own learning pace, which makes studying more compatible with their family life (McVeigh, 2009).

Bell & Federman (2013) assert that the effectiveness of an e-learning course depends on three critical elements. First, stable implementation and development conditions must be maintained throughout the course duration. Secondly, the features of the course, such as depth and interactivity, must be appropriately configured or managed to facilitate the acquisition of different types of knowledge by learners. Third, the challenges faced by instructors in implementing and developing this methodology must be overcome. Examples of these challenges include concerns about academic integrity and student cheating during the activity, as well as concerns about the difficulties faced by low-income students.

The COVID-19 pandemic forced various countries to take measures to prevent its spread and thus avoid the collapse of health systems (Li *et al*., 2020). This pandemic meant keeping distance between people and wearing masks and eye protection, which had a profound impact on the development of different activities (social and economic), including higher education (Chu *et al*., 2020; Li *et al*., 2020; Sipido *et al*., 2020). In this context, higher education institutions (HEIs) had to adapt to maintain the continuity of the teaching/learning process by resorting to various virtual communication platforms (Evans *et al*., 2020). HEIs were forced to abruptly adapt their courses and deliver them entirely in an online format in order to respond to the signs of social distancing, lockdowns and quarantines. In this sense, the subjects of the preclinical cycle that have an important practical component (histology, anatomy, cell biology, physiology, etc.) were challenged to adapt their face-to-face activities (laboratories, workshops, etc.) (Evans *et al*., 2020). Amidst the COVID-19 pandemic, HEIs faced the challenge of adapting their courses entirely to an online format to ensure the continuity of the teaching/learning process, particularly in disciplines like human histology, which involves crucial practical components (laboratories, workshops, etc.). Human histology involves the study of organizational levels that lie between the atomic-molecular level (biochemistry) and the gross morphological level (anatomy) in the human body (Campos-Sánchez *et al*., 2014).

In Chile, medical, nursing, and midwifery programs include histology as part of their undergraduate or preclinical curricula. The histology course we designed was structured on the Moodle platform according to the recommendations of different authors (Chen *et al*., 2005; Godoy-Guzman *et al*., 2019; Evans *et al*., 2020; Pather *et al*., 2020) with content proposed in a synchronous (zoom) and asynchronous (recordings) format. In addition, the course relied on free virtual microscopy (VM) tools. Web-based VM platforms often allow students to review slides at their own pace using web browsers without local software (Krippendorf & Lough, 2005). Several studies have shown that virtual microscopy is a useful and effective tool for teaching histology (Bloodgood 2012; Tian *et al*., 2014; Kuo & Leo, 2019; Lee *et al*., 2020; Caruso, 2021; Darici *et al*., 2021).

In this context, the COVID-19 pandemic provided an opportunity to assess student satisfaction and performance in an e-learning histology course. The data collected from our study may prove valuable in improving the design and evaluation of e-learning histology courses. The study aimed to investigate the impact of an e-learning histology course on the satisfaction of medical, nursing and midwifery students. In addition, we sought to identify the relationship between student satisfaction and performance in relation to e-learning histology courses.

METHODS

We adapted and validated a questionnaire to measure students' perceptions of an e-learning histology course to answer the following research questions (RQs) addressed in this paper:

RQ1: How did students perceive the delivery of a traditional (face-to-face) histology course in an e-learning format?
RQ2: What is the relationship between students' perceptions of the implementation of an e-learning histology course and their academic performance?

Histology Course Design and Curriculum Development: To investigate the perceptions of medical, nursing and midwifery students regarding the adaptation of the histology course, this study was conducted in the first semester of their programs in a prestigious public university in Chile. The histology course lasted 17 weeks or 78 hours of instruction (lectures and laboratories) within these 17 weeks, 7 of these weeks corresponding to laboratory activities. Curriculum construction was under the purview of the Histology Unit Coordinator (last author of this article), the Medicine Curriculum Committee of the university, and also co-instructors of each section. We implemented three strategies to cover the content of the traditional (face-to-face) course (Fig. 1).

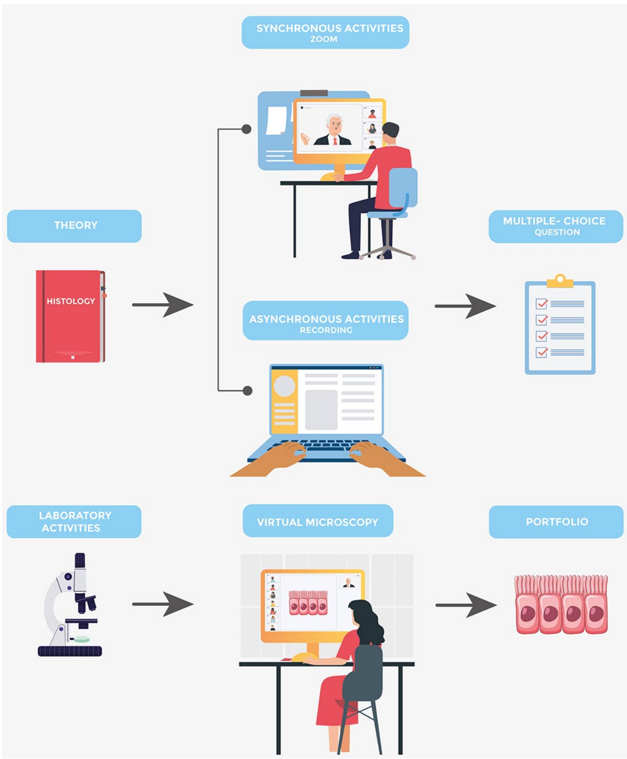

Fig. 1. Proposed model of histology course, showing the three strategies implemented in this study. The top panel shows the components of the theoretical elements in the course which include synchronous activities via Zoom and asynchronous activities (recorded sessions). The theoretical component of the course was assessed by administering multiple-choice questions. The bottom panel shows the virtual microscopy activities monitored by 7 teaching assistants. This component of the course was assessed through portfolios.

First, students participated in synchronous sessions by attending the lecture in real time (Zoom meetings). Second, we included asynchronous activities in which students watched videotaped lectures and videos related to the topic under study in each session (using the Moodle platform). Third, due to the COVID-19 context, we implemented virtual microscopy activities in which 7 teaching assistants worked with different groups of students to monitor them and answer their questions. Figure 2A shows the learning management system (Moodle) used to teach the course and Figure 2B the handout with laboratory activities that students completed during each lesson.

Traditionally, this histology course consists of theoretical knowledge taught in a lecture- based classroom followed by practical sessions in the histology laboratory. This course is offered twice a year. The curricula for the traditional histology course and the e-learning histology version of the course are shown in Table I.

Since laboratories were not available during the pandemic, we used virtual microscopy as a complementary tool to support the practical sessions. Virtual microscopy has been widely used in histology education over the past decades (MacMillan, 2017; Campbell *et al*., 2010) and has been suggested as an effective resource for teaching and assessing histology (Amer & Nemenqani, 2020). Specifically, we used virtual labs freely available on the Internet (e.g., http://zoomify.lumc.edu/ and https://histologyguide.com/) where students were asked to analyze and interpret micrographs to relate structure to function (Figs. 2 C-D). These activities were designed to have students analyze different histological specimens corresponding to basic tissues or body systems. In general, we expected students to be able to identify the general tissue organization of the organ or tissue, cell types, and extracellular matrix elements from a microscopic perspective in order to relate form to function.

The course assessment included two multiple-choice exams and a portfolio. Therefore, an overall score was calculated that included an average of the two multiple-choice exams and the portfolio, which represented the student's academic performance. The exam consisted of 60 questions, 40 of which contained images of structures studied in the virtual microscopy activities. The duration of each exam was 180 minutes. The revision of a portfolio was done in pairs. The portfolio consisted of a compilation of the handouts given during the semester (Fig. 2D). In our course, the portfolios were a didactic tool that allowed students to develop a highly structured and organized framework for the learning materials provided in class, training in histological preparation analysis skills, driving questions and activities related to histological tissue identification (King *et al*., 2019). The portfolios were designed to facilitate students' understanding of the microscopic structures of the human body.

Participants: This study was conducted in 2020 during two consecutive semesters. Two complete cohorts of medical, nursing, and midwifery students enrolled in a histology course consented to participate in this study. To enroll in the histology course, all students had to complete prerequisite courses such as cell and molecular biology or a basic biology course. Although the students in each semester were from different programs, they had similar backgrounds in terms of number of courses taken, same

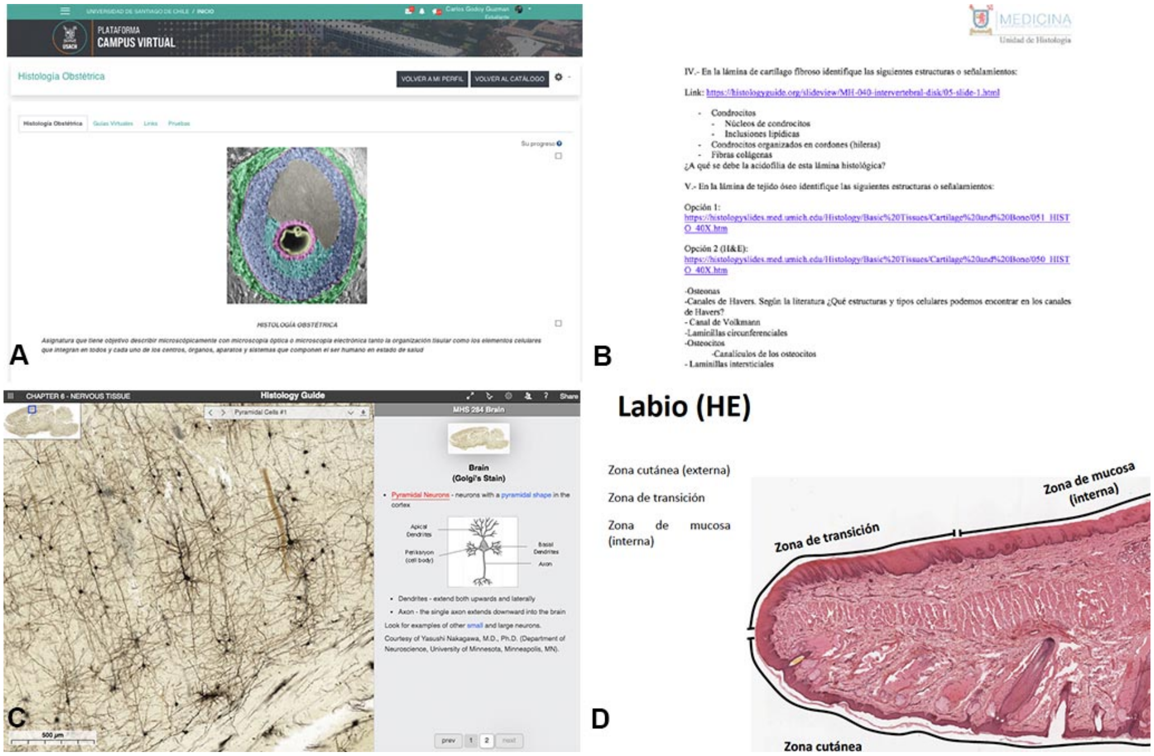

Fig. 2. Image A shows the general characteristics of the e-learning histology course mounted on the Moodle platform. Image B shows the guide that presents the virtual microscopy activities through different links. Image C shows a page from the virtual microscope "Histology guide". This web page shows different contents that deal with general histology and histology of body systems and apparatus. Image D shows an example of virtual microscopy activities developed by medical students in the portfolio. The images from "Histology guide" were reproduced with permission of their authors.

instructors, equivalent curricula, etc. The first cohort of students (first semester: March-July 2020) included a total of 272 second-year students from the same department and faculty as the medical, nursing, and midwifery students who participated in a survey called the Student Perception Online Histology Course (SPOHC). This sample was used to conduct exploratory factor analysis and validate the survey. The second cohort of students (second semester: August-December 2020) included 152 second year students and was used to administer the SPOHC. The study was approved by the university's ethics committee. All study participants were asked for informed consent prior to data collection and were informed that the survey was anonymous and voluntary.

The survey was written in Spanish and consisted of two main sections. The first section of the survey asked for demographic information and included questions about students' habits during COVID-19. This section was used to collect variables that were included in the ordinary least square regression (Table II). The second section of the survey explored students' perceptions of the implementation of a histology course in an online course in response to COVID-19. This section was developed through a review of the online learning literature. Some of the items included in the survey were adapted from other studies related to the quality of online learning experiences (Gómez-Rey *et al*., 2016). In other words, this section, also referred to as the Student Perception Online Histology Course (SPOHC) (Appendix 1), explored students' perceptions of the online course. The survey questions were designed on a 5-point Likert scale ranging from "1 = strongly disagree" to "5 = strongly agree."

The draft SPOHC included 40 items constructed based on the categories of the online learning quality index proposed by Gómez-Rey *et al*. (2016), such as learning support, social presence, instruction, learning platform, instructor interaction, learning content, course design, learner satisfaction, knowledge acquisition, and transferability. To ensure the content validity of the survey, the draft SPOHC was sent to five experts. The experts included two medical technologists, one surgeon, and two Ph.D. biomedical scientists with experience teaching histology. The experts were informed of the purpose of the study, which was to examine student perceptions of the implementation of a histology course during the COVID-19 emergency transition to distance education. The experts were then asked to review the items included in the survey for relevance to the objectives, understandability, and coherence among the

Table I. Example of topics and activities included in the course in in-person format and e-learning histology course.

		Traditional course	E-learning histology course
Week	**Topic**	**Sample lesson activities and assessment**	**Sample lesson activities and assessment**
1	Introduction to the study of medical histology and regenerative medicine.	- In-class lecture - Practical activity: Groups of 40 students and 2 assistant instructors. - The students analyzed different histological preparations through the use of a brightfield microscope. In addition, they learned to recognize basophilic and acidophilic structures in slides stained with hematoxylin and eosin (H&E). - Assessment: True and false questions and open-ended questions related to the identification of key structures. - How is the bright field microscope used? - Most common histological stains. - Handout with instructions on the use of the microscope.	- Synchronous class on general aspects of the study of medical histology. - Forum: Students' discussion about the analysis of virtual slides and questions related to the utility and limitations of scanning electron microscope and transmission electron microscope - Practical activity: Groups of 4-5 students and an assistant instructor. - What is virtual microscopy? Analysis of virtual microscope slide collection examples. - Handout of activities in which students manipulated a virtual microscope.
2	Epithelial tissue: esophagus, thin skin, pancreas, uterine tube, ileum	- In-class lecture - Practical activity: Groups of 40 students and 2 teachers. - Assessment: True and false questions and open-ended questions related to the identification of key structures. - How are the lining and glandular epithelia classified? - Handout of practical activities that guide the face-to-face work in the practical laboratory. Example: In a transverse section of the trachea stained with H&E at 4X, locate the lumen of the tube and at higher magnification identify the epithelium that separates the lumen from the wall of the tube (mucosa). Also, note apical specializations and classify the type of lining epithelium. - Histology drawings generated by students based on the observation in the microscope.	- Videorecorded lecture about epithelial tissue. - Feedback online with students to clarify their doubts. - Is it possible to transform an epithelial cell (keratinocyte) of the skin into a stem cell? Analysis of a video related to the use of pluripotent stem cells in the treatment of macular degeneration and retinitis pigmentosa. - Forum: Publication of micrographs and questions of various types of lining and glandular epithelial tissue. - Practical activity: Analysis of virtual microscope slide collection (esophagus, thin skin, pancreas, uterine tube, ileum). Groups of 4-5 students and teaching assistants. - Handout of practical activities with a virtual microscopy. Example: in the following hyperlink take captures and classify the epithelium lining the mucosa (esophagus). Send your answers to your instructor.
3	Connective tissue: thin skin, umbilical cord, tendon	- In-class lecture - Practical activity: Groups of 40 students and 2 teachers. - Assessment: True and false questions and open-ended questions related to the identification of key structures. - How are connective tissues classified? - Handout of practical activities that guide the face-to-face work in the practical laboratory. Example: identify fibrocytes and collagen fibers in a longitudinal histological section of tendon stained with H&E,. - Histology drawings generated by students based on the observation in the microscope.	- Videorecorded lecture about connective tissue. - Feedback online with students to clarify their doubts. - Uses of the umbilical cord as a source of stem cells. Discussion of micrographs in a group session via zoom (synchronous). - Practical activity: Analysis of virtual microscope slide collection (thin skin, umbilical cord, tendon). Groups of 4-5 students and teaching assistants. - Handout of practical activities with a virtual microscopy. Example: In the following hyperlink (umbilical cord), take captures and classify the tissue that surrounds the blood vessels. Send your answers to your instructor.
4	Cartilaginous tissue and bone tissue: hyaline cartilage, elastic cartilage, fibrocartilage, spongy bone, compact bone.	- In-class lecture - Practical activity: Groups of 40 students and 2 teachers. - Assessment: True and false questions and open-ended questions related to the identification of key structures. - Varieties of skeleton tissues. - Handout of practical activities that guide the face-to-face work in the practical laboratory. Example: Identified tracheal rings (hyaline cartilage) in a cross section of the trachea stained with H&E. Identify chondrocytes, territorial and interterritorial matrix at higher magnification in hyaline cartilage. - Histology drawings generated by students based on the observation in the microscope.	- Videorecorded lecture about cartilaginous tissue and bone tissue. - Feedback online with students to clarify their doubts. - Discussion about a video related to bone remodeling. - Forum: Students' discussion about the analysis of virtual slides and questions about cartilage and bone tissue. - Practical activity: Analysis of virtual microscope slide collection (hyaline cartilage, elastic cartilage, fibrocartilage, spongy bone, compact bone). Groups of 4-5 students and teaching assistants. - Handout of practical activities that guides the work of virtual microscopy (Figure 1B). Example: In the following hyperlink (hyaline cartilage) take captures and identify perichondrium and chondrocytes. Send your answers to your instructor.
5	Muscle tissue: skeletal muscle cells, cardiac muscle, smooth muscle	- In-class lecture - Practical activity: Groups of 40 students and 2 teachers. - Assessment: True and false questions and open-ended questions related to the identification of key structures. - What are the microscopic morphological differences between the 3 types of muscle tissue? - Handout of practical activities that guide the face-to-face work in the practical laboratory. Example: Identify mucosa, submucosa, muscular layer and serosa in cross section of intestine stained with H&E. Distinguish transverse and longitudinal profiles of smooth muscle cells in the external muscle. - Histology drawings generated by students based on the observation in the microscope.	- Videorecorded lecture about muscle tissue. - Feedback online with students to clarify their doubts. - Forum: Students' discussion about the analysis of virtual slides and questions related to the varieties of muscle tissue. - Practical activity: Analysis of virtual microscope slide collection (skeletal muscle cells, cardiac muscle, smooth muscle). Groups of 4-5 students and teaching assistants. - Handout of practical activities that guides the work of virtual microscopy. Example: In the following hyperlink (cardiac muscle tissue), take captures and identify nuclei and intercalary discs in longitudinal profile of histological section. Send your answers to your instructor.
6	Nervous tissue: brain, spinal cord, dorsal root ganglion	- In-class lecture - Practical activity: Groups of 40 students and 2 teachers. - Assessment: True and false questions and open-ended questions related to the identification of key structures. - How are neurons classified? - Handout of practical activities that guide the face-to-face work in the practical laboratory. Example: identified gray matter (neuronal somas) and white matter (nerve fibers) in a cross section of the spinal cord stained with H&E. - Histology drawings generated by students based on the observation in the microscope. - Use of 3D printed spinal cord and nerve models.	- Videorecorded lecture about nervous tissue. - Feedback online with students to clarify their doubts. - Forum: Students' discussion about the analysis of micrographs and questions about different types of neurons and cells of the glia. - Practical activity: Analysis of virtual microscope slide collection (brain, spinal cord, dorsal root ganglion) (Figure 2C). Groups of 4-5 students and teaching assistants. - Handout of practical activities that guides the work of virtual microscopy. Example: In the following hyperlink (spinal cord), take captures and identify motor neurons of the ventral horn. Send your answers to your instructor.
7	Assessment	- 3 Multiple-choice exams that covered disciplinary core ideas and questions related to microscopic images for the identification of key structures (duration 90 minutes). - Identification of structures in histological sheets in the laboratory (10 questions). Duration 40 minutes.	- 2 Multiple-choice exams that covered disciplinary core ideas and questions related to microscopic images for the identification of key structures. Duration 180 minutes. - Revision of a portfolio carried out in pairs (Figure 2D). The portfolio consists of a compilation of the handouts administered in the term.

Note: The sample activities and assessments are detailed in the sequence that they were implemented in each class.

Table II. Variables included in the lineal regression model.

Variables	Code	Range	Description
Outcome variable Academic Performance	Academic - performance	0 - 70	Student academic achievement score. High scores represented a higher level of academic performance.
Independent variables Perception of the course in online format	Perception - course	0-190	A variable derived from students' responses to the SPOHC survey related to their perception of the e-learning histology course into an online format. Participants indicated their agreement with each item on a five-point scale (1 = strongly disagree; 5 = totally agree). An example of item is "38. My knowledge about the contents covered in the subject increased at the end of the course."
Hours of study per week	Hours	0-20	Total number of hours per week dedicated to the study of the course.
COVID-19	COVID-19	0-1	0 = Student considers that COVID-19 did not affect their academic performance 1 = Student considers that COVID-19 affected their academic performance

items. They were asked to rate items as 0 if they thought the item was not essential and 1 if they thought the item was essential. Based on the experts' suggestions, two items from the SPOHC were removed from the draft and necessary changes were made to clarify the remaining items. We used Gwet (2001) Agreement Coefficient 1 (AC1) as an estimate of reliability (Zhao *et al*., 2015), which ranges from -1 to 1. This coefficient is often used to interpret agreement among experts. The benchmark scale includes less than 0.40 as poor, between 0.40 and 0.75 as fair to good, and more than 0.75 as excellent. Values of AC1 ≤ 0 are classified as no agreement (Wongpakaran *et al*., 2013). Gwet's AC1 was calculated independently for each expert, and then an average was calculated to obtain a single index of inter- rater reliability. The resulting index suggested a Gwet's AC1 index of 0.904. In other words, there was agreement among the subject matter experts that the items in the questionnaire were essential for measuring each of the dimensions of the SPOHC. Thus, the final version of the SPOHC contained 38 items and was administered to the second cohort of students (n=152) via an online system. Before administering the SPOHC, we explained the aims of the study and obtained informed consent. The questionnaires were anonymous, and we assured students that their information would remain confidential and that the results would be aggregated.

Measures. A number of variables were selected to examine their relationship with student academic achievement (Table II). The predictors were grand mean centered for ease of interpretation and to avoid multicollinearity, as suggested by Raudenbush & Bryk (2002).

Analysis. For the SPOHC survey, we conducted an exploratory factor analysis (EFA) with the initial sample of students (N= 272). Factor analysis is a common method used to assess evidence of construct validity (Besnoy *et al*., 2016) and to investigate the internal structure of item responses. Factor analysis is also useful for "[reducing] the total number of observed variables into latent factors based on commonalities within the data" (Atkinson *et al*., 2010). EFA with maximum likelihood factoring and direct oblimin rotation was used because of the expected factor correlation. Maximum likelihood is generally recommended as an extraction method (Fabrigar *et al*., 1999). The psych package in R was used for the EFA. The EFA analyses were performed following the suggestions of Preacher & MacCallum (2003). Prior to the EFA, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's sphericity test were performed to assess factorability. To determine the number of factors, an eigenvalue rule greater than 0.3, a commonly used cutoff (Johnson & Stevens, 2001), and parallel analysis and the scree plot test (looking for a change in the slope of the line connecting the eigenvalues of the factors) were explored. Several model fit indices and their criteria were used to examine the goodness of fit of the model to the given data set: Tucker-Lewis Index of Factor Reliability (TLI) (Bentler, 1990), Comparative Index (CFI), Root Mean Square of Residuals (RMSR) and Root Mean Square Error of Approximation (RMSEA) (Hooper *et al*., 2008). The reliability of the factors was examined using Cronbach's alpha.

Ordinary Least Square (OLS) regression was used to examine the relationship between students' perceptions of the adaptation of a histology course in an online format and their academic performance. Data from both samples of students were combined (N = 424) because they represented the same target population. These students had completed similar prerequisite courses, they studied at the same university, in the same department, the curriculum was equivalent, they were taught by the same instructors, and the data were collected in the same way for both samples.

The multiple linear regression model to represent the relationship between the students' perception of the adaptation of the histology course and their academic performance can be written as equation 1:

$$Yi = \beta 0 + \beta 1X1 + \beta 2X2 \ldots \beta nXn + \varepsilon ; n = 1, 2, 3, \ldots \quad (1)$$

Where Y is the dependent variable (students' academic performance), X1, X2, and Xn are explanatory variables or independent variables used as predictors (e.g., hours of study per week), n corresponds to the number of predictors, b0 is the y-intercept (when x-axis = 0), bn is the partial regression coefficient that shows the change in the mean of Y when X increases by 1 unit, holding everything constant (Abdi, 2003), and ε is the random error. For model selection, we used sequential regression (hierarchical or blockwise) in which predictors are included based on theory, logic, or practicality based on their impact on the dependent variable. In the first model (Model 0), only student perception of the course (Perception_course) was included as a predictor. Then, hours of study per week (Hours) and students' perception of the impact of COVID- 19 on their academic performance were each included in the model.

Adjusted R2 was used as the comparison criterion to compare the generated models for linear regression (Faraway, 2014). In addition, analysis of variance (ANOVA) was performed to test whether a more complex nested model was significantly better at fitting the data than a simpler model. After performing regression diagnostics, assumptions of linear regression such as i) independence of errors (Durbin-Watson test), ii) normality (distribution of residuals) by checking histograms and QQ plots, iii) linearity by analyzing scatterplots of standardized residuals against fitted values, and iv) heteroscedasticity by the studentized Breusch-Pagan test (Breusch & Pagan, 1979) were tested. The results of the assumptions showed that i) the Durbin-Watson test (value = 1.37) to test for residual correlations showed values close to the range between 1.5 and 2.5; therefore, we assumed the independence of the errors; ii) the residuals were slightly negatively skewed; iii) overall, the analysis of the Q-Q plot showed the normality of the residuals, but some data points barely touched the line; however, with a large sample size, this assumption can be relaxed and may not affect the inferential procedures because of the central limit theorem, which assumes that the sampling distribution of the sample means tends to be normally distributed (Pek *et al*., 2018). In terms of homogeneity of variance, the analysis of the standardized residuals against the fitted values showed that they were equally distributed. The Breusch-Pagan test was not significant, suggesting that the data are homoscedastic (the variance of the residuals is constant). It is worth mentioning that no influential observations were identified based on Cook's distance criterion (0.5) (Zhang, 2016). In addition, no collinearity problems were identified among the predictors, as the Variance Inflation Index (VIF) statistic was close to 1, and values greater than 2.5 usually indicate a collinearity problem (Allison, 1999).

RESULTS

For the SPOHC, Bartlett's test indicated adequate correlation, $\chi 2$ (703) = 5272.999, $p < .001$, and the KMO test indicated adequate sampling, MSA = 0.9. Bivariate correlations among all questionnaire items did not exceed .90, and the histogram of standardized residuals and the scatterplot of standardized fitted values predicting standardized residuals indicated that multivariate assumptions of linearity, normality, and homoscedasticity were met. Different models were compared and examined for goodness of fit based on the number of factors suggested by parallel analysis (4 factors), scree plot examination (3 factors), and eigenvalues greater than 1.0 (1 factor) and 0.7 (2 factors). A 3-factor model was preferred and tested based on theory. After testing all 38 questions, six items were eliminated from further analysis for two main reasons; i) because they were split across multiple factors or ii) because their factor loadings were less than 0.3. Therefore, another 3-factor model was tested. The factor loadings are shown in Table III.

Table III. Item factor loadings for each factor solution for the SPOHC.

Item	Factor 1	Factor 2	Factor 3	Item	Factor 1	Factor 2	Factor 3
A2	**0.78**	-0.04	-0.13	A8	-0.02	-0.06	**0.69**
A1	**0.75**	-0.02	-0.01	A6	-0.28	-0.01	**0.68**
A3	**0.59**	0.12	0.25	A33	-0.01	0.01	**0.68**
A38	**0.55**	-0.08	0.10	A24	0.08	0.08	**0.65**
A11	**0.51**	0.01	0.26	A9	0.02	0.05	**0.63**
A13	**0.51**	-0.06	0.21	A26	0.04	-0.06	**0.61**
A16	**0.49**	0.20	-0.01	A27	0.06	0.11	**0.61**
A23	**0.49**	-0.17	0.14	A14	0.15	-0.14	**0.59**
A22	**0.46**	-0.20	0.18	A35	0.13	0.03	**0.59**
A17	**0.40**	0.08	0.29	A7	0.14	0.07	**0.57**
A4	**0.30**	-0.20	0.17	A36	0.04	-0.03	**0.57**
A30	-0.07	**0.90**	0.00	A15	-0.03	0.04	**0.55**
A28	-0.03	**0.87**	0.00	A20	-0.07	-0.07	**0.51**
A37	0.02	**0.87**	0.05	A25	0.14	0.10	**0.49**
A19	0.13	**0.76**	-0.06	A32	0.11	-0.10	**0.48**
A34	-0.04	**0.63**	0.02	A18	0.24	-0.28	**0.40**

This simple structure model, in which each item loaded on one and only one factor, showed the following indices of goodness of fit; RMSEA indicated an acceptable fit at 0.064, 90 % CI [.055, .067], RMSR with good fit (0.05), with CFI value close to 0.9, indicating a relatively acceptable fit (0.893), and poor TLI (0.868). Factor 1 included 11 items that measured "E-learning satisfaction". Examples of items in this factor included "4. The content coverage addressed in the course is similar to in in-person classes (for example, general histology or biological bases, biochemical and physical bases of the human body)", "23. The online course helped me develop medical histology skills (e. g., diagnosis of cell types and tissues, analysis of histological preparations)". Factor 2 included five items that appeared to assess "In-person classroom activities". Examples of these items are "19. The face-to-face activities with a conventional light microscope would probably have had a greater impact on my learning compared to the virtual microscopy implemented in the course", and "37. The in-class laboratory activities would have had a greater impact on my understanding of the course content. Factor 3 included 16 items that measured "Course design and teaching quality". For example, item 8 asked "8. Virtual resources such as recorded classes and videoconferences (Zoom) were efficient in reinforcing the theoretical content addressed in each class.", whereas item 36 asked "36. The assessment instruments were consistent with the activities carried out in online format." The reliability of each factor was good for factor 1 (Cronbach's alpha = 0.86, M = 3.7; SD = 0.6); good for factor 2 (Cronbach's alpha = 0.9, M = 3.9; SD = 1.1); and good for factor 3 (Cronbach's alpha = 0.9, M = 4.1; SD = 0.57). The extraction of three factors accounted for 45 % of the variance (Factor 1A = 13 %; Factor 2A= 12 %; Factor 3A = 20 %). Table IV summarizes the results for model fit for the exploratory factor analysis.

Figure 3 displays the means for each item included in the SPOHC, while Appendix 2 provides the descriptive statistics for each of them.

To explore the relationship between students' perception for the implementation of a histology course in online format during the COVID-19 pandemic and their academic performance, we conducted several OLS regressions with different predictors. We used sequential regression in which different predictors were included in the models to explore the fit to the data. The simplest model that best fit the data and that explained the greater percentage of the variance was found to be:

$$\text{Academic\_performance} = 61.05 + 0.06\,(\text{Perception\_ course}) + 0.32(\text{Hours}) - 1.46\,(\text{COVID-19}) + \varepsilon$$

From the equation indicated above, the predictors Perception_course, hours, and COVID-19, were significant predictors of students' performance. By including these predictors (see Model 1 in Table V), the model explained 12.4 % of the variance in the data compared to Model 0, which included only one predictor (Perception_course) and accounted for 6.8 % of the variance. In this sense, Model 1 accounted for 5.6 % more variance than Model 0. The results of the regression indicated that for every unit increase in student perception of the course (Perception_course), student academic performance is expected to increase by 0.06 units, holding all else constant. It was also found that the predictor related to the number of hours per week spent studying the course was significantly positively correlated with academic performance. Interestingly, students who believed that COVID-19 affected their academic performance were expected to decrease their academic performance score by 1.46 units compared to those students who believed that

Table IV. Summary of values for model fit for the SPOHC.

Item deleted	CFI	RMSEA (90%CI)	TLI	RMSR	Reliability of factors (Cronbach's alpha; M; SD)
5, 10, 12, 21, 29, 3	0.893	0.064 [0.055, 0.067]	0.868	0.05	F1A= 0.86; 3.7; 0.6 F2A= 0.9; 3.9; 1.1 F3A= 0.9; 4.1; 0.57

Table V. Models for student academic achievement Score.

	Model 0			Model 1		
Predictor	Estimate	s. e.	*p*	Estimate	s. e.	*p*
Intercept β0	58.83***	0.273	.000	61.05***	0.667	.000
perception_course	0.08***	0.014	.000	0.06***	0.014	.000
hours				0.32***	0.063	.000
COVID-19				-1.46*	0.740	.047
Multiple R-squared	.071			.131		
Adjusted R-squared	.068			.124		

Note: s. e. = Standard error. *** denotes significance level at .001, ** at .01, * at .05. The model with only one predictor (model 0) and the model that best describes the data is included in the table (model 1).

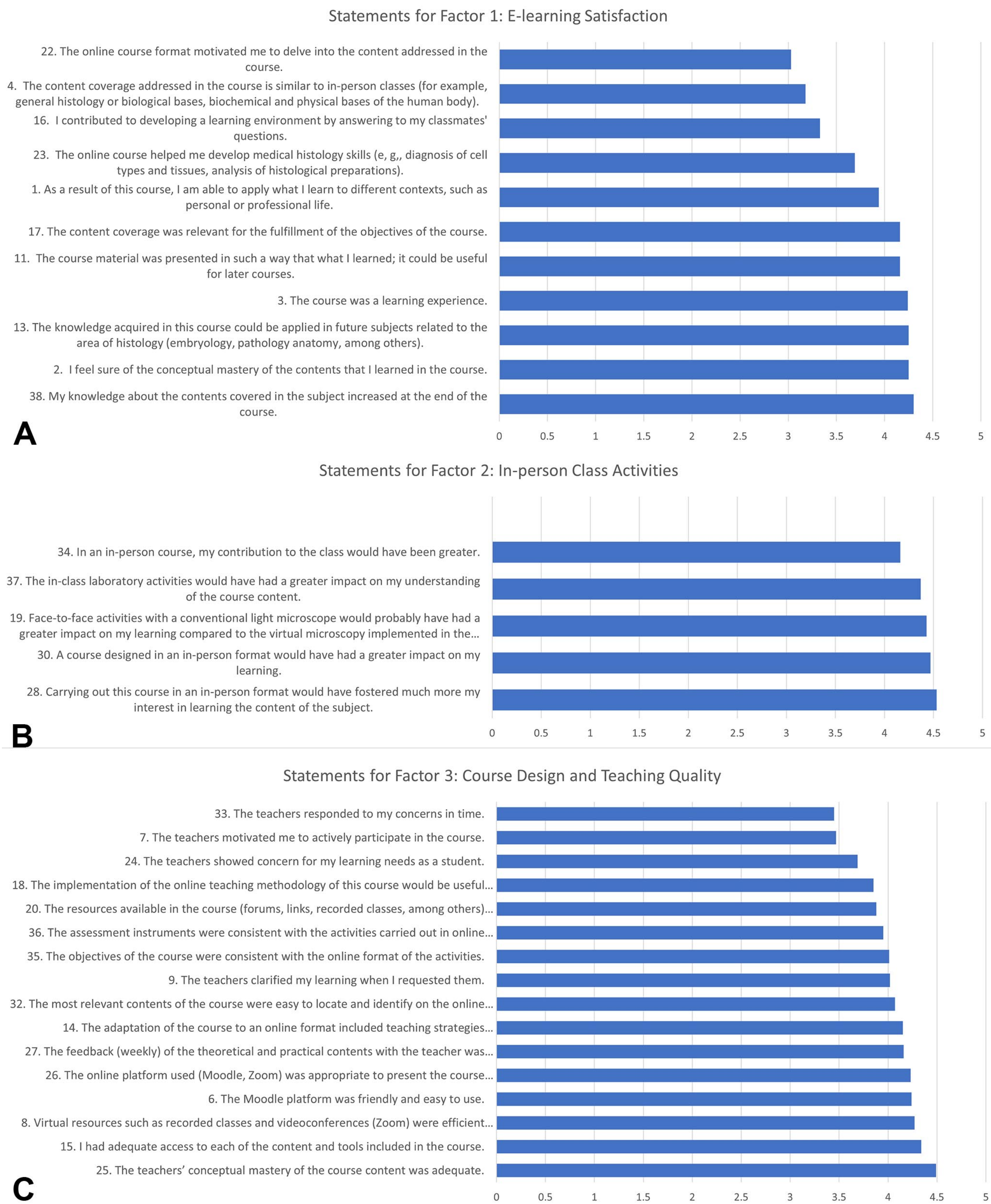

Fig. 3. Results of Likert scale questions "Student Perception Online Histology Course". A) Factor 1:"e-learning satisfaction". B) Factor 2:"In-person class activities". C) Factor 3: "Course design and teaching quality".

COVID- 19 did not affect their performance. Although the regression coefficient of the COVID-19 predictor does not reflect a large difference among students' achievement scores, the result of the regression model showed that this predictor was negative and significantly correlated with students' achievement scores. Table V shows the results of the regression models.

Overall, these results demonstrate that our scale could predict students' perception of i) e-learning satisfaction, ii) in-person class activities and iii) course design and teaching quality for the adaptation of a histology course in an online format as a response to the COVID-19 pandemic; and therefore, provide validity evidence for the scale.

DISCUSSION

The literature on medical and health sciences subjects generally reports positive experiences with e-learning courses (Barbeau *et al*., 2013; Lavender *et al*., 2013; Antonoff *et al*., 2014; Arbour *et al*., 2015; Wilhelm *et al*., 2022). However, there is a lack of published teaching experiences of e-learning histology courses in the global literature (Barbeau *et al*., 2013; Darici *et al*., 2021). Furthermore, although many universities around the world have been using e-learning formats in histology for many years, the conceptualization and implementation of online-only courses in the curriculum has not been systematically evaluated (Darici *et al*., 2021). In this study, we present and evaluate a positive experience of adapting a traditional (face-to-face) histology course to an e-learning format. The course used Zoom as a streaming platform to deliver the course online and Moodle as a virtual environment to download the course material for each class. The course was also supported by free virtual microscopy tools that have been found to be useful for online learning in histology (Bloodgood, 2012; Tian *et al*., 2014; Kuo & Leo, 2019; Lee *et al*., 2020; Caruso, 2021). Assessment of the course included two multiple-choice exams and a portfolio. To investigate students' perceptions of the course, our study sought to provide evidence of the validity of scores derived from the SPOHC in a Chilean population of medical, nursing, and midwifery students. Through EFA, we examined a factorial model consisting of three factors: "e-learning satisfaction", "in-person classroom activities", and "course design and teaching quality". The identified factors could help histology teachers to improve student satisfaction and performance in e-learning histology courses.

The first identified factor corresponded to "e-learning satisfaction". Satisfaction with the e-learning environment is an important aspect in the evaluation of learning environments in general (Virtanen *et al*., 2016). In this sense, students indicate a positive perception of initiators such as "1. As a result of this course, I am able to apply what I learn to different contexts, such as my personal or professional life." and "2. I feel sure of the conceptual mastery of the contents that I learned in the course." In addition, there is a positive perception of indicator "23. The online course helped me develop medical histology skills (e. g., diagnosis of cell types and tissues, analysis of histological preparations)." The above indicators are consistent with the literature on the effectiveness of e-learning courses (Barbeau *et al*., 2013; Srinivasan, 2020; Darici *et al*., 2021; Wilhelm, *et al*., 2022). Darici *et al*. (2021) found that implementing a curricular histology course in an online format during the pandemic period was feasible and effective, using virtual microscopy, for example. Barbeau *et al*., (2013) investigated the effects of an online-only digital histology course in a virtual classroom with synchronous and asynchronous lectures. No significant differences were found between student performance and course evaluations in the online class compared to face-to-face classes and blended classes, where face-to-face and online instruction occurred simultaneously. These results suggest that an online histology laboratory course is an effective format. Wilhelm *et al*. (2022), studied the perceptions, satisfaction, and performance of undergraduate anatomy students during the COVID-19 pandemic. The results of the study showed several benefits noted by the students, such as flexibility in taking exams and learning the material at their own pace. The synchronous activities in this study were conducted using Zoom. Some studies in the field of anatomy have indicated that it is a useful and effective tool (Srinivasan, 2020).

In relation to the second factor identified, "in-person class activities", there is no clarity in the literature on the equivalence in terms of teaching and learning between the face-to-face format and the virtual format (Frehywot *et al*., 2013). The students of medicine, nursing and obstetrics considered that a course in face-to-face format would have had a greater impact on their learning (indicator 30). In addition, they would have had greater interest in understanding the contents of the course (indicator 28), and their contribution during face-to-face histology classes would have been greater (indicator 34). Our results suggest that although the different platforms (Moodle, Microsoft Teams®, Blackboard Collaborate, or Zoom) have been useful to teach histology during the COVID-19 emergency, they do not necessarily replace the experience and learning benefit of the activities carried out in a traditional face-to-face format (Godoy-Guzman *et al*., 2019; Lowe, 2018; Prieto *et al*., 2011; Van Nuland & Rogers, 2017). As Van Nuland & Rogers (2017) point out, one of the greatest challenges in education is the tendency to assume that new technologies are just as effective, if not more so, than traditionally prominent teaching methods. In other fields of morphological sciences, such as anatomy, the difficulty of replacing face-to-face activities such as cadaver dissection sessions, living/surface anatomy, and clinically-focused sessions with hands- on equipment such as ultrasound has been reported (Evans *et al*., 2020; Wilhelm *et al*., 2022). It is also worth noting that students generally felt that face-to-face laboratory activities (light microscopy) would have had a greater impact on their learning (indicator 19) and on their understanding of the subject (indicator 37). Some authors have suggested advantages of using virtual microscopy over using optical microscopy as a teaching tool (Collier *et al*., 2012; Wilson *et al*., 2016). However, our results are in line with those of Xu (2013) and Pratt (2009), who point out various advantages of using optical microscopy in hands-on activities in a traditional format: (i) If students only observe slides through virtual microscopy, they will become unaccustomed to abnormal structures. Because perfect specimens tend to be selected for virtual slides, students may only be exposed to more easily recognizable structures. Then, when they encounter abnormal morphologies in their future work, these students may find themselves in a tight spot. The teaching of histology by light microscopy should remain paramount to train students' practical skills and critical thinking. (ii) Due to the random distribution and imperfect quality of slides in light microscopy, students' questions about structural variations may actually enhance classroom learning and stimulate professional curiosity.

On the other hand, as stated by Frehywot *et al*. (2013), "only when the appropriateness, feasibility and true costs of e-learning tools and methodologies are understood can their impact upon the health of country populations be realized." Therefore, based on what is reported in the literature, we believe that the medical and health sciences (nursing and obstetrics) curriculum should incorporate both light microscopy (traditional format) and virtual microscopy activities depending on the context (pandemic, internet connectivity options, feasibility of personal computers, infrastructure and laboratory equipment). In addition, it is important that curriculum developers and educators consider the different learning styles of students (Mitchell *et al*., 2015) and the diverse professional profile of each program (physicians, midwives, nurses, among others) when building the curriculum (Lowe, 2018).

Regarding the third factor called, "course design and teaching quality", it referred to the curriculum materials, course organization, teaching methods, instructor quality, and feedback in the online course. In this sense, the students positively valued this online teaching course (indicator 18) and the usefulness of teaching strategies such as portfolios, explanatory videos and forums (indicator 14). For example, Gopal *et al*. (2021) found that course design has a significant positive impact on student performance in online courses. In addition, these authors suggest that the way in which instructors deliver course content can affect student satisfaction, performance, and enthusiasm, and thus the quality of the online learning process. It has been described that the success of e-learning courses depends on several factors, the most important of which are the stability of the platform used for the development of the virtual environment, the compliance of the institutions with the characteristics of e-learning, and the continuous improvement and training of the teachers in charge of the different subjects (Selim, 2007). Regarding assessment, surprisingly, Cheng *et al*. (2021), found that students in medical schools believe that feedback must be implemented after online assessment to identify the progress of students in learning outcomes. In this sense, it is worth mentioning that in our histology course, we included feedback in each session (indicator 27), in which teaching assistants clarified students' doubts and recognized their level of understanding for each of the units. Improving online active learning to support the study of medical courses is one of the main difficulties that many instructors face when teaching in medical schools. For example, Evans *et al*. (2020), suggest engaging students in interaction with their peers and tutors, and including synchronous sessions such as webinars or a question-and- answer session to support anatomy instruction. As mentioned in the histology course and curriculum development section, we included forums, hands-on activities, synchronous sessions, and feedback sessions to support student understanding in the course. Although we included feedback as one of the main components in our course, we recognize that one of the challenges in e-learning teaching is to rethink summative assessment to evaluate the effectiveness of instruction and the achievement of learning outcomes.

Finally, a multiple regression analysis was conducted to examine the contribution of the independent variables (students' perception of the course format and hours of study) in predicting the dependent variable (students' academic performance). The results showed that there is a positive and significant relationship between students' perception of the implementation of the e- learning histology course format and their academic performance ($p<.001$). In addition, student performance was found to be positively and significantly correlated with the number of hours per week spent studying the course. As we expected, the results of the regression model predicted that those students who believed that COVID-19 affected their academic performance scored lower than those students who did not. The results of this study regarding the number of hours per week spent studying the course, are consistent with the research conducted by (West & Sadoski, 2011). Their findings indicated that time management was a strong predictor of academic performance in medical school. In addition, our findings provided further support for students' perceptions of the online course in relation to their academic performance. As we expected, study habits related to the number of study hours per week had a positive and significant impact on student performance.

Limitations. First, this study sampled only students from a public university in Chile. The results of this study may not be generalizable to students from other universities and different contexts. We also acknowledge that there could be other external predictors that could have also influenced students' academic performance, such as i) students' motivation and learning styles, and ii) the type of assessment used to measure students' performance, iii) acquisition of equipment (computers or software) and access to Internet connection networks. In addition, students' perceptions of the course may have been influenced by the reduction in the number of hours during the emergency remote teaching compared to a traditional face-to-face academic course.

In this study, we present and evaluate a positive experience with an e-learning histology course. We used three methods to cover the content of the traditional (face-to-face) histology course: synchronous sessions (Zoom meetings), asynchronous sessions (using the Moodle platform), and free virtual microscopy tools. Evaluation of the course included two multiple-choice exams and a portfolio. The current study also addresses the need for an instrument to measure students' perceptions of e-learning histology courses. The instrument we present contributes to the study of students' perceptions of online histology courses by addressing relevant factors such as "e-learning satisfaction", "face-to-face class activities", and "course design and teaching quality". This study provides evidence for the validity of the scores derived from the SPOHC with the removal of one item. The SPOHC can be used to inform curriculum developers and instructors of the aspects of online histology courses that need to be evaluated when designing or adapting a traditional histology course into an e-learning format. In addition, the factors we identified may influence students' motivation and learning in a virtual environment, and therefore have an impact on students' academic performance. Compared to the original questionnaire developed by Gómez- Rey *et al*. (2016) to evaluate the quality of online learning experiences, the SPOHC includes factors that reflect students' perception of the adaptation of practical classes in an e-learning format specifically in histology courses, making the SPOHC an innovative tool specifically designed for this discipline.

Another contribution of the SPOHC is the inclusion of a factor related to "in-person classroom activities". We believe that one of the major concerns of students may be that virtual laboratories cannot fully replace the experience and knowledge they generate and acquire in the laboratory. Measuring the contribution of virtual labs as an alternative to traditional labs, for example due to the increasing cost of hands-on labs or due to the increase in distance education, is an important factor that researchers, instructors, and curriculum developers need to consider when evaluating the quality of an online course and assessing its impact on student learning. Our study also showed that an e-learning histology course can be a valuable teaching method for teaching histology. However, when designing course materials, it is important that curriculum developers and instructors focus not only on providing disciplinary knowledge, but also on encouraging students to develop and enrich their practical knowledge and skills in microscopy. In the context of medical courses, the results of this study showed that students do not perceive e- learning practical activities as fully analogous to face-to-face learning, since the latter requires the development of skills that are more likely to occur in the laboratory (e.g., observation of abnormal morphologies, critical thinking skills, among others).

Because this instrument is new and was developed based on other studies, researchers are encouraged to continue to refine the scale. Future studies need to focus on validating the results of the exploratory factor analysis and applying the questionnaire to another population. Factor structure results are often affected by sample data, and further research is needed to avoid sampling bias and confirm the latent variable structure (Kim *et al*., 2016). Finally, the results of this study are useful for researchers and instructors who can use the survey to identify the components of online courses that are better perceived by students, and also to inform about specific sections of the adaptation of an online course that need to be revised or enriched. This information can be used to promote changes in future versions of the course.

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GONZALEZ DONOSO, A.; JARA-ROSALES, S.; ROSEMBLATT, M.; OSSES, M.; PADILLA-MEZA, J. & GODOY-GUZMÁN, C. Impacto de un curso E-learning de histología en la satisfacción y desempeño de estudiantes de medicina, Enfermería y Obstetricia. *Int. J. Morphol., 42(4)*:1161-1174, 2024.

RESUMEN: La importancia y relevancia de los cursos e-learning en medicina y ciencias de la salud ha aumentado significativamente en la última década. A pesar de ello, existen pocas experiencias docentes publicadas de cursos de histología e-learning en la literatura a nivel mundial. El curso de histología que diseñamos se estructuró en la plataforma Moodle, y los contenidos se propusieron en formato síncrono (zoom) y asíncrono (grabaciones). También incluimos el uso de herramientas gratuitas de microscopía virtual. Este estudio tuvo como objetivo investigar el impacto de un curso de histología e-learning en la satisfacción y el rendimiento de los estudiantes de medicina, enfermería y obstetricia. La muestra incluyó 424 estudiantes chilenos de medicina, enfermería y obstetricia de dos cohortes. Se aplicó una encuesta tipo Likert al final del curso. Se realizó un análisis exploratorio y una regresión por mínimos cuadrados ordinarios. En este estudio, presentamos una experiencia positiva de un curso de e-learning de histología. El análisis factorial exploratorio reveló tres factores principales relacionados con la "satisfacción sobre el aprendizaje e-learning", "clases presenciales versus clases virtuales" y el "diseño del curso y la calidad de la enseñanza". También encontramos que existía una relación positiva y significativa entre las percepciones de los estudiantes sobre la adaptación del curso de histología tradicional (presencial) a un formato e-learning y su rendimiento académico. Nuestro estudio muestra que los cursos de histología e-learning que integran clases teóricas y sesiones prácticas pueden ser una valiosa herramienta de enseñanza. Los responsables de la elaboración de planes de estudios y los profesores de histología deben tener en cuenta las limitaciones y ventajas de este tipo de enseñanza y sugerimos incorporar estos tres factores al diseño y la evaluación de los cursos de histología en línea.

PALABRAS CLAVE: Educación médica; Educación en profesiones de la salud; E-learning; Curso de histología; Satisfacción de los estudiantes

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