Personalised learning model for academic leveling and improvement in higher education

Lizette Susana Hernandez Cardenas, Leticia Castano, Cristina Cruz Guzman, Juan Pablo Nigenda Alvarez
Tecnológico de Monterrey

This study's innovative objective was to develop a personalised learning model to equate students' entry level knowledge as they entered the School of Medicine and Health Sciences at Tecnologico de Monterrey in Mexico in 2019. This was necessitated by a difference in the depth and approach to preparatory content. The methodology focused on adapting the learning process to the students' specific knowledge requirements in cell biology and chemistry courses to enrich knowledge and improve academic performance. We implemented a diagnostic test at the start of the course to determine the students' level of mastery in these subjects. The students were allowed to learn at their own pace and were expected to improve their low initial scores by constructing their learning paths. The professor served as an advisor. At the end of the course the students retook the exam to measured the difference between the diagnostic test results and the terminal level of knowledge. The research design was non-experimental, observing the phenomenon as it occurred in the natural context, using an interval-type scale (quantitative) questionnaire. The analysis of the learning model's results showed an increase in the students' knowledge and satisfaction and demonstrated the model's usefulness for understanding educational content.

Implications for practice or policy:

- This study presents a personalised learning model that emulates adaptive learning and provides flexibility and autonomy to students for acquiring knowledge.
- The participating students self-assessed their entry level of knowledge in chemistry and biology via the online diagnostic test using Canvas, the learning management system (LMS) of Tecnologico de Monterrey.
- The ability to asking questions to the professors, in synchronous feedback sessions, was facilitated by the interactive communication platform, to enrich the learning experience.

Keywords: personalised learning, adaptive learning, knowledge-leveling, academic improvement, educational innovation, qualitative analysis, higher education

Introduction

New generations of students require learning experiences aligned with their profiles (e.g., previous knowledge, learning styles), interests, and experiences that approximate real-life contexts. Personalised learning is a method that leverages existing learning theories and the practical experience of educators and students to modify the learning environment to meet the students' needs (Walkington & Bernacki, 2020). Integrating the vision of the students and the teaching team allows for customisation of experiences that support the students' learning processes.

The School of Medicine and Health Sciences at Tecnologico de Monterrey recognised that new students have different entry levels of knowledge in the core courses of cell biology and chemistry, in the Bachelors of Biosciences, Nutrition and Comprehensive Wellbeing, and Biosciences of Clinical and Health Psychology, Surgeon and Dental Surgeon programs. Therefore we developed a personalised learning model to equatethe students' entry knowledge to ensure they have the same level of knowledge by the end ofthe first academic period.

This study's innovative objective was to develop a personalised learning model to help students acquire and fortify the basic knowledge in cell biology and chemistry necessary for the first year of health sciences. The study also aimed to create educational experiences that adapt the teaching-learning process to the specific knowledge needs of the student, using a variety of digital learning resources.

The outcomes of this study were as follows:

- This was the first time the institution offered these leveling courses designed in this format and helped the students at the beginning of their professional programs.
- The professors collaborated to design the courses and develop the digital learning resources.
- The digital learning resources designed by teachers and the curated resources were integrated to support a micro content format.
- The content was delivered to the students using the institution's learning management platform (LMS) resources and emulated adaptive learning.
- Each student customised their learning path at their own pace (when) and format (how), for their learning needs (what) and access requirements (where).
- The LMS platform presented teachers and students with information on student progress so the professors could provide feedback.

Theoretical framework

Prerequisite knowledge for the area of medicine

At the international level, the Organization for the Economic Co-Operation and Development (OECD) began the Program for International Student Assessment (PISA) to measure the knowledge and skills acquired by students at the end of secondary school education and their ability to apply them in various situations and contexts (PISA, 2016). The test was applied in different countries throughout the five continents, comparing education in sciences, mathematics, and literacy skills (Rodríguez-Vargas et al., 2015). In Latin America, the PISA scores (2016) in science were 19% below the worldwide average, which led to the establishment of guidelines for the curricular redesign of secondary and upper-middle education in that region. It has previously been shown that the students who become professionals do not have all the necessary foundations for their professional studies or lives (PISA 2016).

Each year at the School of Medicine and Health Sciences of Tecnologico de Monterrey, students enrol from all over the world. Therefore, professors must work with students who have varying knowledge levels in cell biology and chemistry and other fundamental courses, to help students develop competencies in their chosen professional careers. Due to this situation, the need arose to develop courses that equate the students' entry level knowledge and create a solid base for their professional careers.

However, we noted that one of the main challenges for professors was how they could identify students who already knew a lot about each of the topics. A secondary issue was to determine if the students' current level of knowledge was enough to understand the contents of the first semester courses toward their degree. Thus, we developed a diagnostic test to identify the differences in contents and contexts, to enable the assignment of topics and areas. By receiving the diagnostic test scores, the students could identify the topics they had already mastered, and those that required more focus. It is also important to mention that this diagnostic test was administered to all the students during their School of Medicine and Health Sciences admissions process.

From a theoretical standpoint, Bombelli & Barberis (2012), mention that diagnostic evaluations have an exploratory function. They evaluated students' characteristics in the teaching process regarding their previous knowledge, which was directly related to learning, skills and competencies, interests, motivations, and disposition to study new contents. Moreno (2016), held that such evaluations (diagnostic) needed to yield reliable results. We agree with Moreno (2016) that designing an instrument with the appropriate technical quality is crucial to achieve the desired purpose, that is, to find the students' strengths and weaknesses to reduce dropout rates, maintain academic continuity, and improve academic programs.

Knowledge levelling

The literature provides evidence that a globalised environment of education generates competitive arenas (Hernandez-Coló, 2019). Higher education institutions must evaluate their programs to ensure educational programs' quality and effectiveness, relevance, processes, and sufficiency for the teaching-learning process. For example, Vilardi et al. (2020), recognised three benefits to students of implementing leveling courses before entering the pharmacology program. First it allows the students to remember the necessary fundamentals they may have learned a considerable time ago. Second, it allows the students to transition to a professional level higher than high school but lower than the curriculum to be studied. Third, it allows professors to detect students who may face problems in their first year of studies and then design teaching and learning strategies to improve the students' knowledge and skills.

Rodriguez-Vargas et al. (2015), reported that the Universidad Autonoma de Zacatecas detected the need to level the knowledge of students entering the physics program. They used two optional curricular plans. The traditional program required 4 years, and the students entered directly into the program's subjects. The second option proposed a year of preparatory courses that level the students' knowledge in physics and mathematics. It was found that the dropout rates were lower in this preparatory program than the traditional program (Rodriguez-Vargas et al., 2015).

Klausner et al. (2019), mentioned that at the South College School of Pharmacy, in the United States, the need to level students' knowledge was due to first-time students' differing contextual variables and experiences. They designed a program offering courses to facilitate the undergraduates' transition before admission to the pharmacology career course (Klausner et al., 2019). Their program runs for 2 days and was optional for students. Theoretically, disciplinary topics such as organic chemistry, anatomy, medical terminology, study techniques, professional ethics, and institutional services were covered in this program. The program's implementation increased the GPA of the participants by 0.32 points in 2015 (when the students were not offered the class) and 2019 (when students took the course).

Other pharmacology-related universities that have offered undergraduate transition courses include the Louisiana College of Pharmacy in Xavier University, which in a 4 week program covers ethics, cultural skills, biomedical immunology, human anatomy and physiology, and pharmaceutical biochemistry. The Creighton University School of Pharmacy and Health Professions program lasts for 8 weeks and focuses on biology, chemistry, mathematics, physics, and cultural awareness. Another example is Northeast Ohio Medical University, with an online pre-entry program that reinforces study skills, cell biology, anatomy, and mindfulness. Northeast Ohio's program begins before admission and is maintained throughout the entire curriculum.

Personalised learning

Martínez-Hernández et al. (2016), defined tools that facilitate building personalised learning, such as information management through curated network resources, content creation, and interconnectivity to share the information acquired. Accordingly, this study defines personalised learning as integrating three relevant points of view or theoretical frameworks. First, per UNESCO International Bureau of Education (2017), personalised learning consists of paying particular attention to students' prior knowledge, needs, capacities, and perceptions during the teaching-learning processes to adapt future contents to their identified learning requirements, problems, or needs. In other words, personalised learning prioritises each student's needs and goals, and tailors instruction to address those needs and goals. These needs, goals, and progress towards meeting them, are apparent and easily accessible to the professors and students. The goals and content are frequently discussed among both parties and updated accordingly (Pane et al., 2017). Finally, the purpose of personalised learning is that the students can apply practical and personal meaning to what they learn and have the possibility of choosing (Coll, 2015). As illustrated in Figure 1, personalised learning solutions must include or emphasise: (i) what the students learn, (ii) when they learn, (iii) where and with whom they learn, and (iv) how they learn.

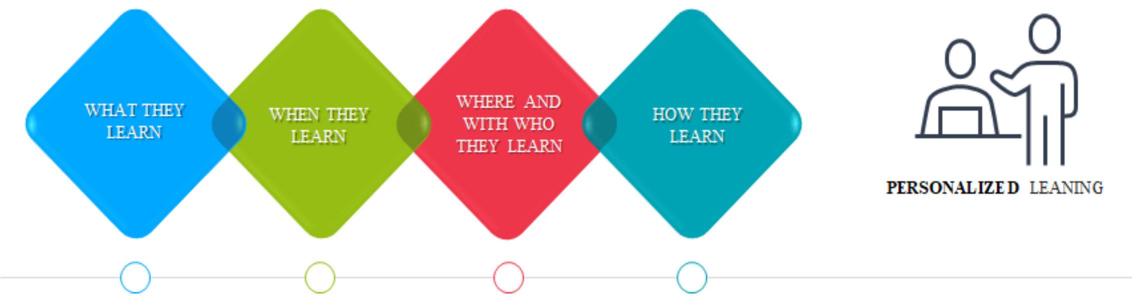

Figure 1. Purpose of personalised learning

The LMS needs to have the capacity to allow students to create individual profiles, or personalised personalised learning trajectories, which can motivate the students to establish and manage their individual academic goals (Cavanagh, 2014). Instruction, feedback, and correction should be adjusted based on interactions with the professors and the students' demonstrated performance levels. Practically, personalised learning adapts and anticipates the content and resources that the student will need at a specific time to progress in their learning process (Tecnológico de Monterrey, 2017).

Given the above findings, this study defines personalised learning as an educational approach that adapts each student's learning based on their individual needs, strengths, abilities, and interests, providing them flexibility in what, when, how, and where to learn during their curriculum and various training experiences. Different strategies and technologies provide degrees of autonomy and choices for the students to own their learning process in these settings. This project presents a methodological strategy for the flexibility and autonomy given to students in their knowledge acquisition process.

Adaptive learning is a personalisation method, which according to Lowendahl et al. (2016), is a process that dynamically adjusts how content is presented to students. With adaptive learning, the content is adapted according to the students' understanding of the material, their evaluation results, and their preferences of materials (e.g., videos, audios, text). For Dziuban et al. (2016), it is a process in which the courses are organised as a series of nodes or learning packages that include content and evaluations. The different packages form a learning path, with a unique sequence for each student depending on the chosen learning package. The assessments in each package determine which package will be recommended to the students next. Students can also select the package they want to study, however, they must first demonstrate the required performance level (Dziuban et al., 2018).

Palazón Herrera (2015), defines *microlearning* as interconnected, short-duration forms of learning with activities offering micro contents. Thus, microlearning and micro contents are closely related. Micro contents are an essential part of microlearning, which refers to small efforts done in 5 to 15 minute short sessions. Microlearning is small, so the time required for review or study should also be small.

Based on the above findings, we designed two leveling courses in this study, leveraging the advantages of personalised learning and adaptive learning, integrating these in a LMS that allows the student to have flexibility in what, when, how and where they learn. Fundamentally, the content was presented via various types of digital learning resources (documents, multimedia resources, activities, and assessments). Thus, the personalised learning model described in this paper is innovative, in that the microlearning structure differs from the traditional model. It allows the students to embrace different ways of learning, reduce knowledge gaps and reinforce their learning.

Methodology

Biology-chemistry personalised learning model emulating adaptive learning

The personalised learning model proposed in this study responds to the need to level knowledge in cellular biology and chemistry among first-year students of Medicine and Health Sciences at the Tecnologico de Monterrey School of Medicine. The model can also be applied to other learning contexts or settings. This innovation began in January 2019 with the diagnostic test design and the structure of two courses, one for cell biology, The Biology of the Human Cell, and the other for chemistry, Biostructures: The Origin of Life. The teaching of the educational activities in August 2019 culminated with evaluating the learning model's leveling courses in December 2019.

In practice, this personalised model's didactic sequence was based on diagnosing the student's level of knowledge, assuring the understanding and practice of the concepts, and integrating the acquired knowledge with other study areas. Figure 2 presents the didactic strategy, the functional elements that interacted in the teaching-learning process, how they did it, and the resources they used.

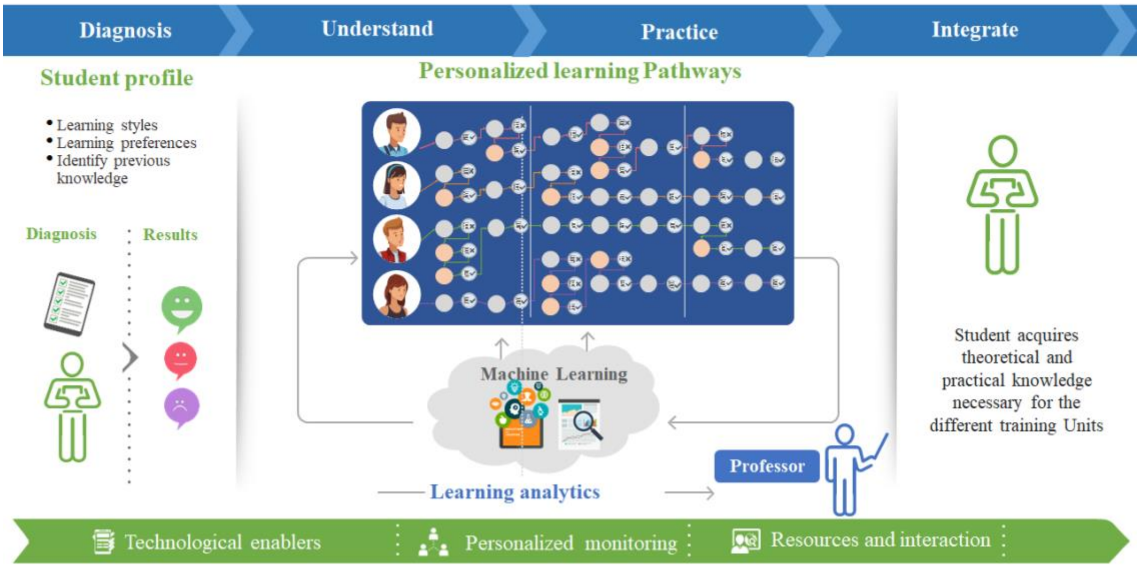

Figure 2. Didactic sequence for the biology-chemistry personalised learning model

As illustrated in Figure 2, this personalised learning model differs from the traditional model because it has the following educational experiences that make it innovative and attractive to students:

- Self-directed learning: the student chooses what to study.
- Personalisation: content chosen by the students according to their learning needs.
- Online content is always available.
- Flexible duration and format (type of resources).
- Interactive: facilitates the students' interactions with educational resources.
- Short duration: short contents in various formats (microlearning).
- Iterative: the resources can be reviewed as many times as necessary to acquire mastery.
- Portable and mobile: contents viewed from any device.
- Reusable: the concepts can be applied to various topics.

The course was made available in Canvas, the LMS used by Tecnologico de Monterrey. This LMS allows contents to be available at any time and place, and interfaces with any device. Both courses had the same structure within the LMS system. The only difference was the number of subtopics that made up each syllabus. There was a homepage in CANVAS with each course's general information, the syllabus, the means of contact for follow-up with the teaching staff, and direct access to the topics that made up the course. The students also had access to the assessment center that integrated their evaluations by topic and the contents for consulting resources with adaptive bases. The students reviewed a base resource (the primary resource that explains the content), reinforcement resources if necessary (complementary resources for improving the learning), and took a formative evaluation to measure their comprehension of the topics studied.

Students' learning outcome and experience in the biology-chemistry personalised learning model

The biology-chemistry personalised learning model began with a diagnostic test taken by students to measure their required knowledge in cellular biology and chemistry before entering the Health Sciences professional programs. The results were able to indicate low-scoring subjects, which needed to be reinforced. The students then began the leveling courses in cell biology and/or chemistry and had 5 weeks to complete them. The students were able to learn at their own pace, reinforce low-scoring knowledge, and use various digital resources to learn the study concepts.

At the end of each subtopic, the students answered a quick test and received immediate feedback. They could advance to the next concept or revisit the previous one based on the results. In this way, each student generated their personalised learning path depending on the concepts they reviewed (Figure 3). The professor had an advisory role, intervening when the students had questions after studying all the digital resources available for learning the concepts.

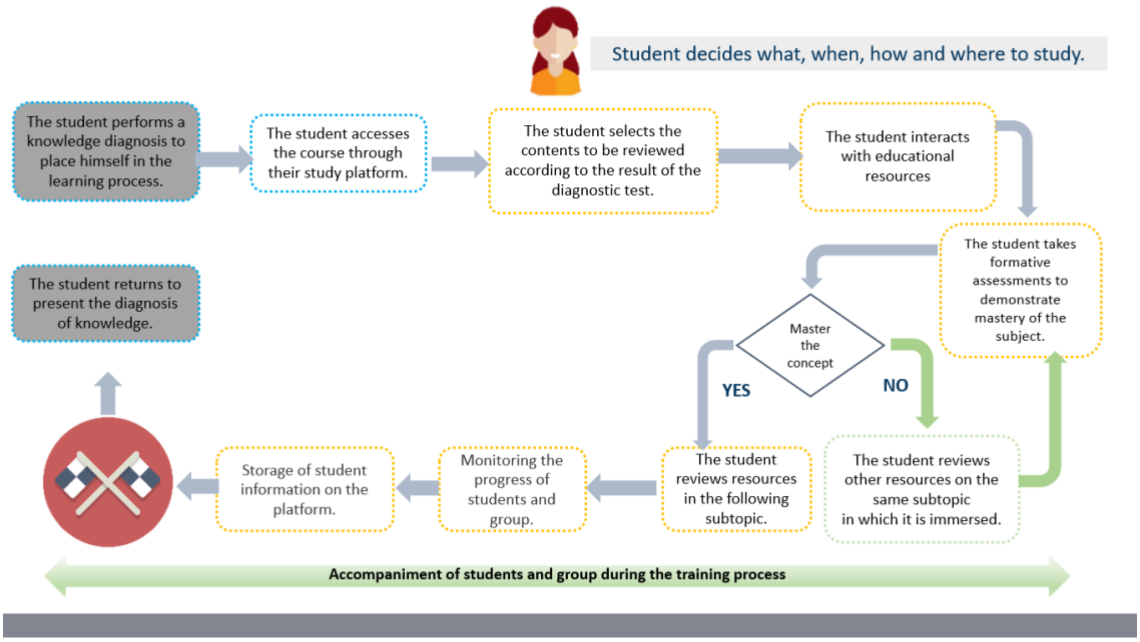

Figure 3. The student's study process

Figure 3 shows that personalisation in the model comes from the students building their learning path to understand the educational content and know their performance in the assessments. Figure 4 shows the student's specific learning process and the enabling components within the technological platform.

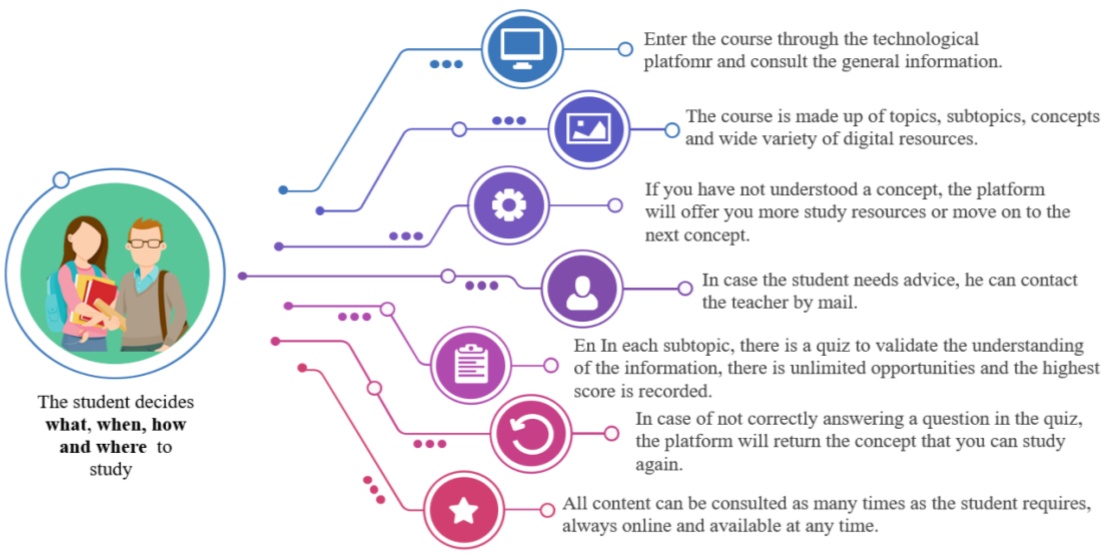

Figure 4. Student's personalised learning process and course components

Personalised learning path

The information presented to the students through micro-content allowed the construction of learning paths according to each student's needs. To achieve this content granulation, the agenda was defined by topics, subtopics, and, finally, concepts. Short-term digital educational resources explained the concepts as shown in Figure 5.

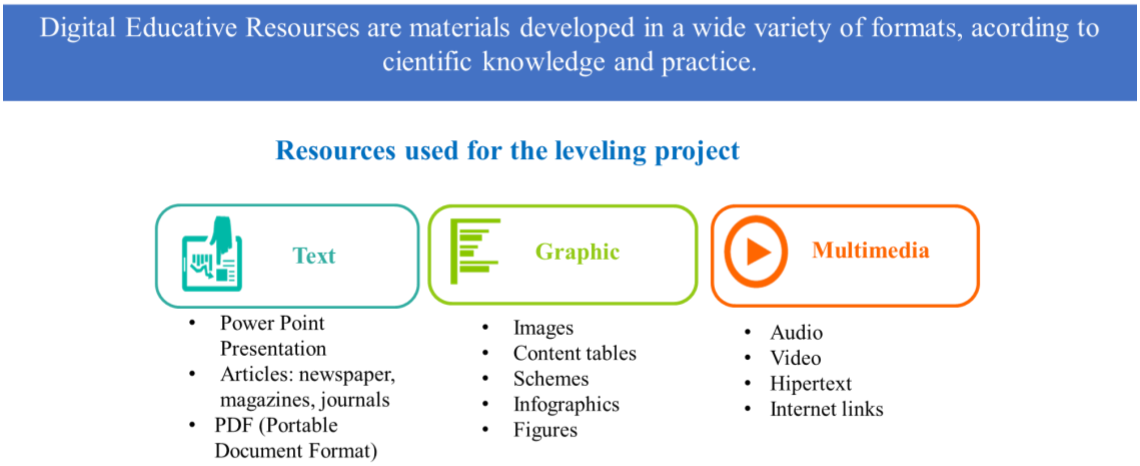

Figure 5. Composition of digital learning resources

As shown in Figure 5, each concept was organised by a base resource (e.g., text, graphic, multimedia) and several reinforcement resources. When the first base resources appeared, the student could begin to study the concept. If the student required additional information, the platform displayed the reinforcement resources that consolidated the contents (Figure 6). The resources were of two types:

- Created: developed by the professor
- Curated: selected from the Internet, with a contribution from the professor

After completing a subtopic, the student took an assessment to check the level of the acquired knowledge, and moved on to the next subtopic. The students could take the evaluation as often as required and revisit or consult the resources whenever necessary.

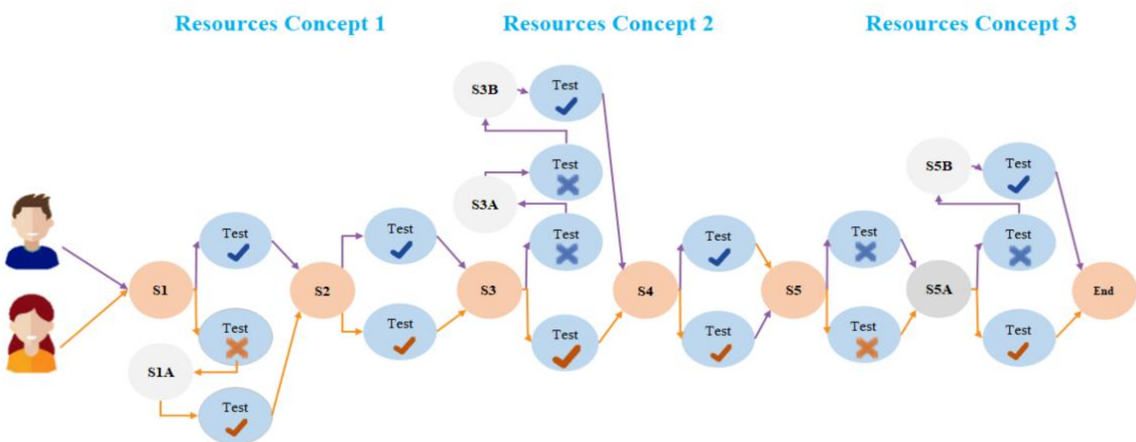

Figure 6. Personalised learning path

Figure 7 shows the course tree structure that presents each topic's subtopics, the evaluation for each subtopic, its concepts, and the three resources for each concept.

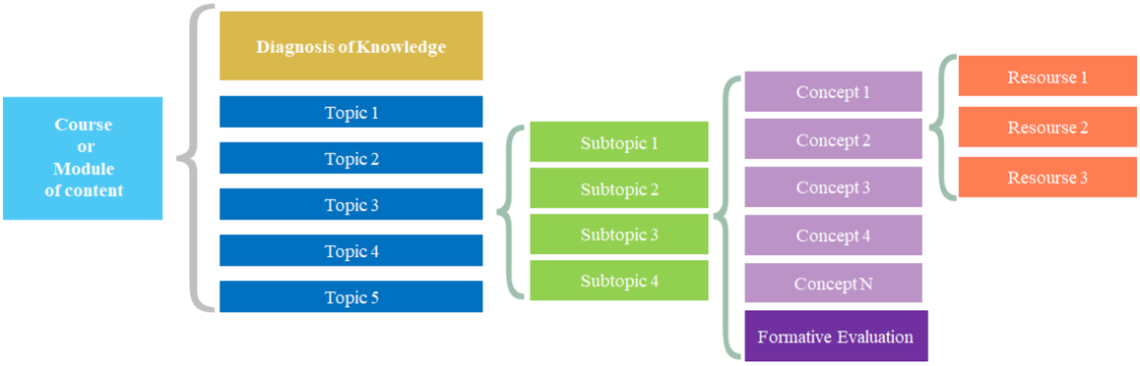

Figure 7. Structure of the personalised learning platform navigation tree

The educational innovation implementation and process

The process we followed to develop the innovative learning platform in January 2019 is described below:

a) Workshop with professors: Develop the syllabus and the concepts for the diagnostic test.
b) Diagnostic examination design: Develop the questions and calibrate the instrument.
c) Construction of learning routes: Create or curate digital educational resources and develop 62 evaluations (quizzes).
d) Construction of the Canvas technology platform structure: Develop the content navigation tree for each course's learning routes by topic, subtopic, and concept and integrate the quizzes.
e) Operational review of the platform routes: Verify that the learning routes coincide with what was planned, a correct presentation of topics, subtopics, concepts, resources, and evaluations. The objective of this review was to detect errors both in the pedagogical navigation components and the digital learning resources access.
f) Definition of the delivery model: The leveling courses were taught online with an advisory professor who followed up the students' progress and answered their questions. Each student advanced at their own pace. Some finished early, while others took until the end of the period.
g) Evaluation of the educational experience: Design and validate the instruments to determine the impact on the courses based on academic performance and students' experience.

The study design was non-experimental, observing the phenomenon as it occurred in the natural context, and data collection was via an interval-type scale (quantitative) questionnaire. The interval-type scale questionnaire was designed with six sections analysed and evaluated in this study, as follows: general information, course structure, content, the platform, study method, and general satisfaction.

A non-probabilistic sampling technique was used. The survey was sent to all students enrolled in first year Biostructures: The Origin of Life ($N = 218$) and The Biology of the Human Cell ($N = 228$). A representative response was obtained from 254 participants. Also, it is essential to mention that demographic and academic data were requested from all the students enrolled in the semester, even when they did not take the remedial courses. A stratified sample was used to make comparisons between the groups, depending on the criteria. The results obtained were based on the academic performance of students in the initial and final diagnostic examinations.

Results

The personalised learning model emulating adaptive learning in biology-chemistry was evaluated to determine if it was an effective solution for new students, especially to see if it offered an opportunity in areas of disciplinary knowledge that influenced their study profile, the instructional model, or the technological platform supporting academic performance and educational experience. In August 2019, the courses had the following numbers of students and participants in the survey (Table 1).

Table 1
Students in the health sciences leveling courses

	Chemistry			Cell biology		
	Students enrolled in the course	Survey participants responses	Response rate	Students enrolled in the course	Survey participants responses	Response rate
Mexico City	51	16	31.4%	50	21	42.0%
Guadalajara	80	44	55.0%	78	63	80.8%
Monterrey	87	52	59.8%	100	58	58.0%

Figure 8 compares the average grades obtained by the students in the initial and final exams of both courses. For the chemistry (biostructures) course, students initially attained an average of 46.9 cumulative points (which made them candidates to take the course), and in the final exam, they scored an average of 87.6 points. In the initial cell biology course, the average score was 42.1 points, and after taking the course, the final exam performance was 80.9 points.

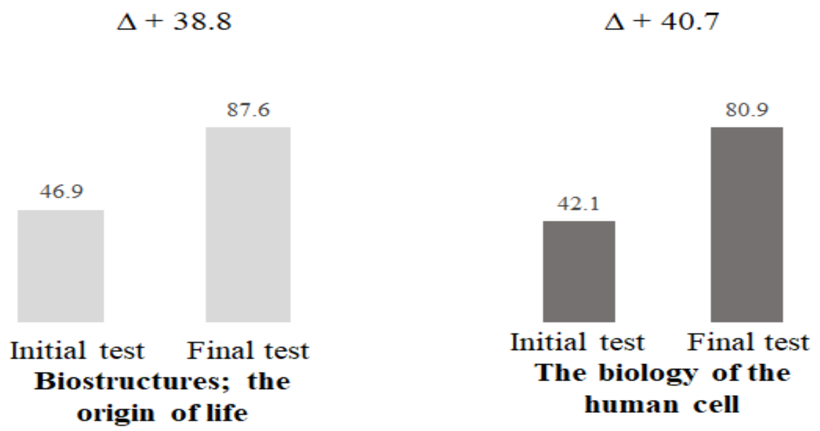

Figure 8. Graph representing the students' academic performance

Perception of general satisfaction with the model

In the survey, the students were asked about their general level of satisfaction and educational experience considering the following questions:

- Custom course design. Whether they like the design of the course.
- Contents and variety of resources. Whether they like the contents of the course.
- Lessons learned. Whether they were satisfied with what I learned in the course.
- Overall experience. Whether they were satisfied with the whole experience in the course.

Figure 9 shows the results of the students' perception and general satisfaction with the model in the chemistry course. The survey items were measured on 4-point scale ranging from *totally agree* to *totally disagree*.

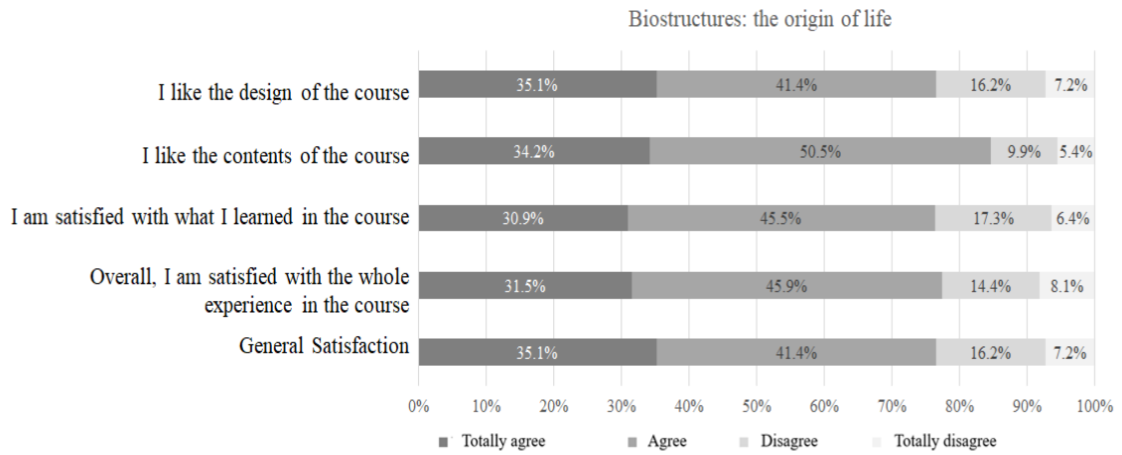

Figure 9. Graph representing the students' perception and general satisfaction of the model in chemistry

Figure 10 shows the results of the students' perception and general satisfaction with the model in cell biology, which was measured on a 4-point scale ranging from *totally agree* to *totally disagree*.

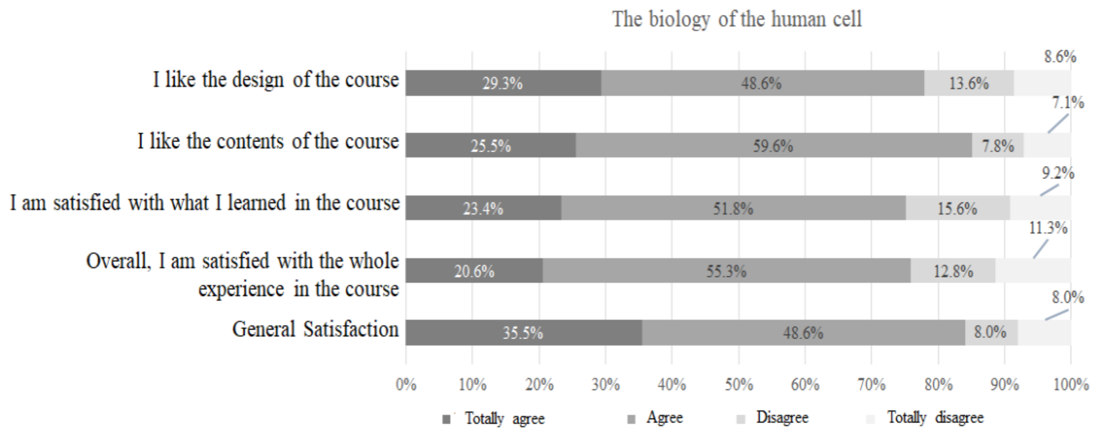

Figure 10. Graph representing the students' perception and general satisfaction with the model in cell biology

Perception of the personalised structure of the course

The students were asked their opinions on the primary resources, reinforcement, format varieties, and other personalised learning aspects. The results below considered the following questions:

- The base resources allowed me to understand the topics (85%).
- Supporting resources helped me to attain sufficient knowledge to understand the topics (82%).
- I like to have a variety of formats for consulting content (80%).
- I like the personalised structure of the courses (cell biology and chemistry) (89.5%).

Discussion

Statistically, observing the results shown in Figure 8 for both courses there was a significant increase in the mean of more than 38 points in the final exam over the diagnostic test. Based on these results, we concluded that the courses increased the students' knowledge of cell biology and chemistry. Moreover, these results were consistent with those reported by Palazón Herrera (2015), where microlearning educational resources of 5 to 15 minutes duration positively impacted the students' learning. Further, when we compared the results with other methods found in the literature, Palazón Herrera (2015) who confirmed that using micro contents promoted learning. The results also showed that the strategies we designed to migrate learning from the classroom to any place and time, highlighted the importance of microlearning methods that allow students to learn freely whenever and wherever they want.

In the survey, we evaluated five criteria: personalised course design, content and resources, acquired learning, general experience, and general satisfaction. Regarding personalised course design, we concluded that the students were satisfied with the design of the courses as we observed satisfactory and acceptable ratings of 77.9% for chemistry and 76.5% for cell biology. The quality of the contents and resources created and curated by the teachers were very satisfactory and of significant impact or influence for the students, who rated them 84.7% in the chemistry course and 85.1% in cell biology, respectively. Also, students felt satisfied with the learning acquired and reflected a satisfaction level of 76.4% for chemistry and 75.2% for cell biology.

Regarding general experience, the chemistry students rated it 76.95%, and the cell biology students 80%, which indicated an acceptable overall satisfaction by the students and provided us with indicators for the future continuous improvement of the process. A continuous improvement process will be applied to update the implemented learning resources, including the evaluation instruments, teachers' training, and strategies for design improvements in future studies. For instance, the diagnostic instrument's questions will be assessed and recalibrated to confirm that they adequately measure the students' knowledge. This implies the analysis, revision, and construction of new questions for the diagnostic test's general redesign.

Conclusions

Tecnologico de Monterrey facilitates innovative learning and provides the resources to support it. Given the need for a new curriculum, we formed a group of teachers to work collaboratively to define the diagnostic evaluation and the contents to be covered based on the curricular requirements of the training units. A personalised learning model emulating adaptive learning and using microlearning was developed to improve cellular biology and chemistry knowledge among students entering the undergraduate School of Medicine and Health Sciences during 2019. The second objective was to increase their knowledge during the semester by applying the model. The students learned at their own pace, generating their personalised learning paths. The professor acted as a guide and gave feedback to the students through synchronous sessions using the interactive communication platform.

The model increased students' knowledge by more than 38 points on the final assessment compared to the initial diagnostic test. Students' satisfaction was 84.1% in chemistry and 80.1% in cell biology. The students agreed that the base resources allowed them to understand the topics, and the support resources were sufficient to understand the study concepts. Finally, the various formats for consulting content (multimedia and texts, for example) served the different student learning styles. Content availability using any mobile device gave students the flexibility to decide when and where to access their learning. The Canvas LMS platform allowed us to present the microlearning contents flexibly to the students regarding what, when, how, and where learning takes place, thus, emulating adaptive learning. The platform used the resources already available in the institution, allowing the professors to follow up on the students' progress.

In summary, to measure the impact of the leveling courses on the first semesters' training units, we plan to use a quantitative methodology to contrast the results obtained in the training units of those students who took the leveling courses versus those who did not. This learning model can be used in any other area where the students have educational lag or differences in pre-knowledge levels. A leveling course can be designed with the same premise of personalised learning through adaptive topics. Last but not least, this learning model can be replicated at the high school and undergraduate levels for mathematics and physics subjects in engineering degree programs and the conceptual level for humanities subjects.

In conclusion, this project presented a methodological strategy to provide flexibility and autonomy to students in their knowledge acquisition process. The study used personalised elements or components to help the students identify their needs through the Canvas LMS. The diagnostic test results helped the students to choose which resource materials they needed. While we did not considered the technical aspects, we concluded that the students in other study contexts could use this model to approach the contents or topics they study.

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Corresponding author: Cristina Cruz Guzman cristina.cruz@tec.mx

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