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RESEARCH ARTICLE

QR CODE: THE KEY TO MORE ACTIVE LEARNING IN IMMUNOLOGY EDUCATION

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ABSTRACT

Immunology is a branch of biology that studies the immune system, which is responsible for defending our body against everything it recognises as foreign, such as bacteria, viruses, fungi, parasites, and even our own cells that have become harmful, as in the case of cancer. Teaching this subject is challenging because many immunological concepts are abstract and difficult to visualise. However, by using appropriate pedagogical strategies and innovative teaching resources, it is possible to facilitate learning and make immunology a more accessible and engaging topic. Implementing new teaching strategies will not only update students' knowledge but also contribute to improving the overall quality of education in this field. In this project, QR codes, Virtual Classroom, and Padlet were used to teach cellular and humoral immunity topics. The percentage of acceptance and learning was calculated through validated questionnaires using a Likert scale. The results demonstrated collaborative work and the development of key skills among students, making it easier for them to understand the concepts. Among the tools used, QR codes were the most popular among the students, likely because they felt more immersed and participatory in the learning process.

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INTRODUCTION

Immunology is the branch of biology that studies all the defence mechanisms an organism has to protect itself from external agents that could harm it. These agents can be microorganisms, such as bacteria, fungi, and viruses. However, it is also capable of acting on substances that are not potentially pathogenic, like dust, and even foreign substances such as pollen. Humoral immunity is based on the production of antibodies by B lymphocytes. These antibodies bind to antigens and mark them for destruction by other cells of the immune system. (Abbas, Lichtman, & Pober , 2017). Cellular immunity is carried out by T lymphocytes, which recognise and destroy cells infected by viruses or cancerous cells. They also coordinate the overall immune response. (Abbas, Lichtman, & Pober , 2017). This brief description, as well as more in-depth topics, are taught in immunology courses. The teaching of immunology often focuses on memorising concepts without emphasising the understanding of underlying mechanisms, and students may struggle to apply theoretical knowledge to real clinical cases. (Siani, Duboxi, Borushko, & Haskel-Itá, 2023). Understanding the immune system is fundamental for the development of the course, which is why it is necessary to incorporate new digital tools to help students learn and make teaching easier for educators. (Amaro de Chacin, 2011). The effectiveness of a technological tool largely depends on the design of the activities and tasks that are implemented. It is important to create meaningful activities that take advantage of the specific features of each tool. Educators need to receive proper training to use these tools effectively and maximise their pedagogical potential, so they can convey this knowledge correctly to students during the school year in the appropriate manner and at the right time. (Siani, Duboxi, Borushko, & Haskel-Itá, 2023). The results show that they can vary depending on the educational context (educational level, subject, etc.). The use of QR tools, Virtual Classroom, and Padlet are part of the Technology for Research, Communication, Knowledge and Digital Learning (TRCKDL) (Barbolla C, Benavente n, López , Martín , & Serrano , 2013). QR codes encourage student participation by inviting them to explore and discover new information. They facilitate access to videos, articles, interactive exercises, and other supplementary materials, making learning more enjoyable and engaging. (Barbolla C, Benavente n, López , Martín , & Serrano , 2013). A study recommends that universities, along with their educators, leverage technological advancements such as Padlet to create and design virtual teaching-learning spaces. (Dominguez Herrera, 2024). Another study involving the use of QR codes indicates that they promote mobility and accessibility, as they can be linked to diverse content. Unlike other visualisation technologies, QR codes do not pose issues related to version compatibility or the operating systems of mobile devices. (Meneses Fernández, Mrtín Gutierrez, & Alvarez Martpinez, 2014). These results motivated the idea of incorporating them into the teaching of immunology.

MATERIALS AND METHODS

Virtual Classroom: The Virtual Classroom is an online learning environment that simulates a traditional classroom but in a digital format. Through the internet, teachers and students can interact, share materials, carry out activities, and conduct assessments, all from anywhere with an internet connection. It offers a personalised learning environment, facilitating interaction and

access to diverse educational resources. It encourages collaborative work and allows for flexible assessments through forums, chats, and video conferences (Ruiz, 2023). An open-source Moodle platform, which is highly flexible and customisable, was used. In this Virtual Classroom, students had access to explanatory videos as well as theoretical concepts of immunity. The way to access a virtual classroom varies slightly depending on the platform used, such as Moodle (https://moodle.org/) or Google Classroom (https://sites.google.com/view/ classroom-workspace). All that is needed is an email address from the company or institution, in this case, UNAM (Universidad Nacional Autónoma de México), which generates a username and password. Students then need to search for the web address provided by the professor

Padlet: Padlet (https://padlet.com/) is a digital tool that allows for the creation of collaborative murals in a simple and intuitive way. It is like a virtual bulletin board where digital sticky notes can be posted, enabling the organisation of information in a visual and appealing manner, which facilitates collaboration between students and teachers (Oviedo, 2023). Padlet is an independent platform that does not need to be integrated with other tools to function. It is created from an account, and from there, all murals can be designed and managed.

QR Code: A QR code generator is used. When the QR code is scanned with the camera of a mobile device (smartphone or tablet), it decodes and displays the information that needs to be shown to the student. (Barbolla C, Benavente n, López , Martín , & Serrano , 2013). In this study, several QR codes were provided to students, containing information for accessing the virtual classroom, direct links to videos on immunology topics, and access to relevant articles on the subject. The tool QR Generator (https://online-qr-generator.com/) was used to generate the codes that were given to each student.

Questionnaires on Internet Accessibility and Digital Tools: Before carrying out the activities, students were given a questionnaire to ensure they had proper access to the platforms, as well as devices capable of connecting to the internet and using the digital tools. (Bernal torres, 2016). These questionnaires were validated using Cronbach's alpha methods and a Likert scale, and the analysis of variance (ANOVA) was used to determine whether there were significant differences in accessibility to the internet and digital tools (Box, Hunter, & Hunter, 2017). This questionnaires helped to ensure that all students had access to a smartphone, an internet connection at FES Zaragoza, at their homes, and could download the necessary applications for reading QR codes, accessing the Virtual Classroom, and using Padlet. (Gomez, 2016).

Questionnaires on Acceptance and Learning Methods: To evaluate the impact these tools had on learning and student acceptance (Box, Hunter, & Hunter, 2017), questionnaires were also used, validated with Cronbach's alpha methods and a Likert scale. (Gomez, 2016). The ANOVA allowed for determining whether there were significant differences in the acceptance and learning of the digital tools, QR codes, Virtual Classroom, and Padlet (Arribas, 2004). These questionnaires were given at the end of each presentation of a topic. In the first part, students were asked to rate, on a Likert scale from 1 to 5 (where 1 meant "totally disagree" and 5 "totally agree"), ten statements related to: the organization of ideas, the ease of use of the tool, its ability to foster collaboration between class users, its perceived usefulness, the improvement in the ability to present information, its flexibility to adapt to different tasks, the increase in student motivation, the willingness to recommend the tool to others and, finally, general satisfaction with its use. The second part included ten statements, also evaluated on the same scale, that explored whether the tool had facilitated the understanding of immunological processes, whether it had helped to differentiate key concepts and whether it had contributed to better understanding the mechanisms of humoral and cellular immunity. The percentage of acceptance and learning was determined by adding all the responses marked as 'totally agree' on the questionnaires. The result was divided by the total number of students to obtain the percentage.

Development of the Activity: The objective of the activity was to consolidate basic knowledge about humoral immunity and cellular immunity. The functioning of each digital tool used (Virtual Classroom, Padlet, and QR codes) was explained, and teams of five members were formed. Each group received a different QR code that directed them to a document with specific information about a component of the immune system (humoral immunity and cellular immunity). Subsequently, each group created a presentation on Padlet to share their findings. The presentation included a brief explanation of the immune system component. Additionally, each group presented their work in the Virtual Classroom by creating a video conference, which included a Q&A and comments section. The professor guided the discussion and clarified doubts throughout the process. At the end of each presentation, individual learning was assessed using acceptance and learning questionnaires, the quality of the information presented, the clarity of the explanations, and the originality of the visual representations. The students' ability to work in groups, share responsibilities, and reach agreements was also analysed.

Group and Population: In our study, the sample consisted of Group 3353 from the Dentistry program during the 2023-2024 academic year, with a total of 30 students. Of these, 20 were female and 10 were male. All students were regular attendees, and 1% of them worked. The group was homogeneous as they were all subjected to the same academic stress and followed the same study plan. (Hernández, 2013).

RESULTS

Table 1. Results obtained from acceptance and learning of the methods

TRCKDLE	% Acceptance	% Learning
Virtual Classroom	84%	80,5%
Padlet	92,6%	88,7%
QR Code	96,6%	93%

The results in Table 1 show the outcome of calculating student acceptance and learning based on the questionnaires given after each activity. The QR code received the highest percentage of both acceptance and learning.

DISCUSSION

It is important to note that these results are only a reference and that the effectiveness of the TRCKDL tools may vary depending on various factors, including the educational context, the characteristics of the students and the way in which the tools are implemented. (Arista, 1914). During my experience as a teacher, I observed a significant increase in student participation when QR codes were used. In this study,

students were provided with several QR codes containing access to the virtual classroom, direct links to videos on immunology topics, and access to relevant articles on the subject. This indicates that, even though students were exposed to the same content, their acceptance varied depending on how the information was delivered. By interacting through their smartphones, students felt more engaged in the learning process, experiencing a sense of immersion that motivated them to explore and learn more independently. Unlike virtual classrooms and Padlet, QR codes offer a more dynamic and effective learning experience due to their versatility. The use of smartphones, devices widely available among students, allows for immediate access to a wide range of educational resources. The results of the first questionnaire support the idea that QR codes are an accessible and efficient tool, as all students have access to a smartphone. The incorporation of playful and competitive elements through QR codes motivates students, encourages interaction, and personalises the learning process, making the content more engaging and relevant to them. There is a significant positive correlation between the percentage of acceptance and the percentage of learning. This suggests that the more a tool is accepted, the higher the likelihood that users will learn effectively with it. This assertion could be further strengthened if a similar study were conducted with a larger population. Additionally, it would be useful to compare this teaching modality with traditional methods to evaluate the impact on acceptance and learning effectiveness.

CONCLUSIONS

All the technological tools presented a very high acceptance rate, exceeding 80%. This suggests that users are generally satisfied with these tools and find them useful. The QR code stands out as the tool with the highest percentages in both acceptance and learning. This could indicate that QR codes are a particularly effective tool for teaching and learning in this context (it would be highly beneficial to continue implementing QR codes in other topics for teaching purposes). The results indicate that QR codes, Padlet, and virtual classrooms are technological tools with a high level of acceptance and can be used to enhance learning. However, it is important to consider the specific characteristics of each tool and design activities appropriately to maximise their potential.

Key Points

- New technological tools can make wake more interest in the students
- QR is preferred by the students. It is believed it is because they play a role into getting the information and is not solely present to them.
- A comparative study between two groups, one with traditional techniques and another one with technological tools

Conflict of interests: The authors declare that there are no conflicts of interest in this study.

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Glossary

TRCKDL: Technology for Research, Communication, Knowledge and Digital Learning
ANOVA: Analysis of Variance

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