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RESEARCH ARTICLE

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Influence of the use of 3D printing technology for teaching chemistry in STEM disciplines

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Abstract

Teachers can create engaging learning environments in engineering courses through pedagogical innovation using Information and Communication Technologies (ICT). Introductory chemistry courses in Science, Technology, Engineering and Mathematics (STEM) disciplines typically include the study of molecular models and periodic properties, which are inherently visual concepts. Unfortunately, these concepts are often taught using two-dimensional drawings, although three-dimensional (3D) printing offers an engaging approach to learning chemistry in these disciplines. Undergraduate engineering students are provided with modelling software and a 3D printer, allowing them to construct 3D models of basic Valence Shell Electron Pair Repulsion theory shapes using polylactic acid. The results of this research showed that the average score of the students in the control group was lower than that of the students in the 3D technology group. This research has found that the learning curve for modelling and the time required for printing are high, limiting the practical application of this exercise in student laboratory classes. However, in an appropriate environment, 3D printing technology has the potential to be a valuable tool for teaching and learning molecular models and periodic properties of chemistry courses in STEM disciplines.

KEYWORDS

3D printing, chemistry, learning, modelling, teaching

1 | INTRODUCTION

Learning chemistry can pose a number of challenges for students. Some of the most common problems include understanding abstract concepts and theories and chemistry anxiety, as some students develop an aversion to chemistry due to previous negative experiences or perceptions of the subject as difficult. In addition, the lack of educational resources and adequate support, whether in the form of teachers or educational materials, can be a crucial factor for success in learning chemistry [6, 7]. Three-dimensional (3D) printing can be a useful tool to enhance chemistry learning [15]. For example, 3D printing of molecular models can help students better visualise molecular structures and understand how atoms interact in a molecule 1. In addition, 3D printing can help students better understand abstract concepts in chemistry, such as stereochemistry and molecular geometry.

3D models are an essential tool for chemistry teachers as they facilitate the visualisation of molecules in three dimensions and support kinaesthetic learning. Copolo, Hounshell [5, 13, 18]. As it can be challenging for students to convert the two-dimensional representation of a molecule seen on paper into a 3D image, there is a clear need for physical representations of these molecular models. As a result, many molecular models have been developed and commercialised for use by teachers and students in the teaching and learning process. The commercial success of molecular model kits is based on their modular nature, allowing students to assemble, modify and disassemble them according to their needs. Unfortunately, these models are often small, making them less suitable for teaching to large groups of students, such as at university level, particularly in lecture-based classes. To overcome this problem, the use of larger models has been discussed in the literature. However, their limited flexibility and high cost generally limit their widespread use [8]. In addition to the development of molecular models, studies have also described the development and use of molecular orbital models [4, 16].

On the other hand, the periodic table is a fundamental tool used in many scientific disciplines. It provides a framework for organising and analysing different chemical and physical properties. Understanding the structure of the periodic table enables students to make logical predictions about variations in atomic radius, ionic radius, electronic configurations, electron affinity, ionisation potential and/or effective nuclear charge. Therefore, the ability to use the information contained in a periodic table is essential for understanding the basic concepts of chemistry required in many scientific and engineering disciplines. In the teaching and learning process of basic chemistry concepts, it is important to consider not only the importance of managing and understanding the table and periodic properties, but also the significant difficulties associated with memorising these concepts, which often lead to confusion and fundamental conceptual gaps. Recently, numerous activities have been described in the literature to improve the teaching and learning process in the field of chemistry [14, 17]. Specifically, with regard to the content and properties of the periodic table, many teachers and researchers have developed and incorporated activities that facilitate students' learning of these concepts [1, 3, 11, 12].

3D printing has been increasingly used in engineering and science, even at the industrial level, due to its ability to facilitate rapid prototyping and product development [2]. More recently, it has been used for laboratory-scale scientific innovation in diverse fields such as microfluidics and analytical chemistry [9, 10]. In addition, the ability of 3D printing to easily and cost-effectively produce complex and customised objects enable educators to incorporate it into the teaching and learning process. The kinaesthetic component of using modelling and 3D printing, as well as the subsequent use of the models, is particularly important, as this type of learning is uncommon in the field of chemistry and has been shown to increase students' attention in the classroom and their ability.

In this study, 3D printing technology was used to evaluate students in a chemistry-related subject. The aim of this work was to improve the teaching-learning process in the classroom and to increase class participation. The evaluation of the methodology and the students' perception were analysed by comparing the students' grades with those of a control group. In addition, a satisfaction questionnaire was completed by the students at the end of the course.

2 | MATERIALS AND METHODS

2.1 | Materials

A FlashForge Finder 3D printer model, as well as various polylactic acid (PLA) filaments in a variety of colours, were used to represent different atoms, types of bonds, and periodic properties. The Socrative application was used to evaluate and develop of the pretest and posttest questionnaires. This open and free application is a virtual platform developed by Berté et al. [19] that is available on computers and mobile devices.

2.2 | Methods

2.2.1 | Teaching intervention context

The subject 'General Chemistry', which is part of the first-year curriculum in various degrees and double degrees offered at the Higher Polytechnic School of the University of Seville (Bachelor's degrees in Industrial Design and Product Development Engineering, Industrial Electronic Engineering, Electrical Engineering, Mechanical Engineering, Industrial Chemical Engineering, and Double Degrees in Electrical Engineering and Mechanical Engineering, Industrial Design and Product Development Engineering and Mechanical Engineering, and Electrical Engineering and Industrial Electronic Engineering), includes 10 h of laboratory classes to be completed by each student. These laboratory classes are divided into five 2-h sessions where experiments related to the theoretical concepts taught in the theory classes are carried out. The subject is divided into three modules: Applications of Chemistry in Industry and the Environment, Structure of Matter and Transformation of Matter. However, these laboratory classes are only related to one of the three thematic blocks or modules of the subject, specifically the one concerning the transformation of matter. Additionally, there are 5 h of computer classes conducted in small groups. Since the transformation of matter module is difficult to put into practice due to its theoretical and abstract nature, a teaching intervention involving the use of 3D Technology has been devised.

2.2.2 | Participants

Integrating 3D printing technology into university chemistry education offers a transformative and immersive learning experience that goes beyond traditional methods. By using 3D printing, students can engage in hands-on exploration of molecular structures, chemical reactions and complex concepts that may otherwise be difficult to grasp through traditional two-dimensional representations. This technology enables the creation of intricate and tangible models of molecular structures, allowing students to visually and tactilely understand the spatial relationships between atoms and molecules. This not only improves understanding, but also fosters a deeper appreciation of the 3D nature of chemical phenomena. In addition, 3D printing facilitates the customisation of educational materials, allowing educators to tailor their teaching resources to meet specific curriculum requirements or individual learning needs. The interactive and dynamic nature of 3D printed models encourages active student participation, fostering collaborative problem solving and critical thinking skills essential for success in the field of chemistry. Ultimately, incorporating 3D printing into chemistry education not only modernises teaching methods, but also creates a more engaging and effective learning environment for students.

The activity involved implementing a 2-h laboratory workshop and two 1-h seminars, focusing on the modelling and production of molecular models and chemical compound structures. The sessions also included a theoretical and practical explanation of the key aspects of the molecules involved, such as bonding, 3D structure, and bond angles. Out of the total number of students from the degree programs, 67 students ($N_{3D} = 67$) participated in these sessions as part of the study group, referred to as the 3D Group from now on. The remaining students from the different degree programs followed the traditional methodology for laboratory classes and computer seminars. The 3D Group was divided into smaller groups of 8–12 students from various degree programs. Among the students who did not participate in the new methodology, a control group (CTL Group) of 45 students ($N_{CTL} = 45$) was established, also divided into groups of 8–12 students. Since this subject is part of the first year of undergraduate studies, the students' ages ranged from 17 to 23 years. The students in the 3D Group had access to a computer with installed software to visualise the different models provided to them. Additionally, a FlashForge Finder 3D printer and various PLA cartridges in different colours were available for all students.

2.2.3 | Methodology and procedure

Table 1 shows the thematic distributions used in the 3D Group and the control group for the laboratory classes and seminars in the subject of General Chemistry, ordered chronologically based on when they were taught. The main differences between the two groups were the

TABLE 1 Thematic and temporal distribution of seminars and laboratory practices in the subject of General Chemistry for the groups in which 3D technology was used (3D Group) and the control group (CTL Group).

Type of teaching	3D Group	CTL Group
Seminar 1	3D Modelling	Formulation of inorganic compounds (I)
Seminar 2	Molecular models and structures. VSEPR theory	Formulation of inorganic compounds (II)
Seminar 3	Formulation of inorganic compounds (I)	Formulation of inorganic compounds (III)
Seminar 4	Formulation of inorganic compounds (II)	Formulation of organic compounds (I)
Laboratory 1	Study of the periodic table and periodic properties	Introduction to the chemistry laboratory
Seminar 5	Formulation of organic compounds	Formulation of inorganic compounds (II)
Laboratory 2	Introduction to the chemistry laboratory	Chemical reactions
Laboratory 3	Chemical reactions	Acid-base equilibrium
Laboratory 4	Acid-base equilibrium	Electrochemistry
Laboratory 5	Electrochemistry. Evaluation of the laboratory sessions	Evaluation of the laboratory sessions

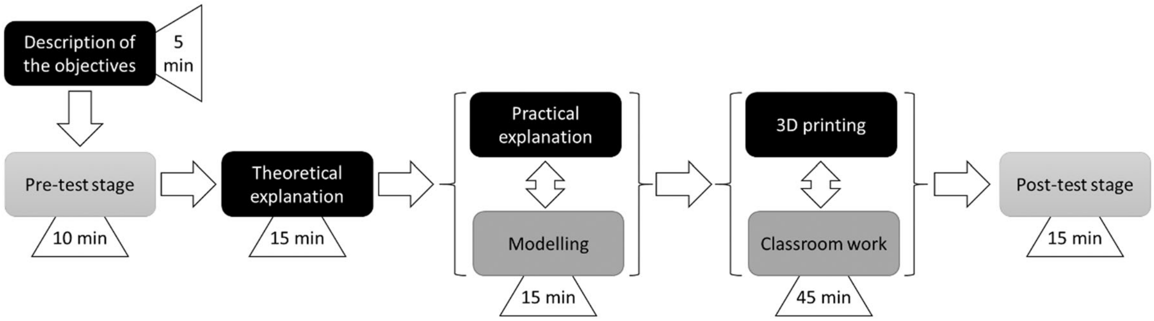

FIGURE 1 Methodological model applied in the group of students who have used three-dimensional technology (3D group).

introduction of 2 h of seminars (1 and 2) on modelling and studying molecular structures, as well as 2 h of laboratory time for studying the periodic table and periodic properties. The inclusion of these new hours for the use of 3D printing technology brought about other changes. Specifically, the hours dedicated to the formulation of inorganic and organic compounds were reduced, and the evaluation of laboratory classes was integrated into the Electrochemistry session. The influence of these changes on student motivation, grades, and the perception of the teaching staff will be analysed. In particular, for evaluating student learning during the 3D technology session, questionnaires were conducted using the Socrative application and divided into two stages:

(i). Pretest Stage: A questionnaire was administered before the teacher's explanation. The free Socrative application was used to prepare and conduct the questionnaires, which can be accessed via internet-connected phones, tablets, or computers. This questionnaire consisted of 20 multiple-choice questions aimed at assessing students' prior knowledge of the concepts necessary for the practical session.

(ii). Posttest Stage: A new questionnaire was conducted, containing half of the questions from the pretest stage and 10 additional questions on new concepts that may have emerged during the 3D technology session. This allowed the evaluation of whether there was an improvement in results compared to the previous stage during the experimental part.

Figure 1 shows a diagram illustrating the methodology used for the sessions in which the 3D printer was used. The diagram shows the order in which the 2 h were delivered. It is important to note that seminars 1 and 2 in the 3D group are considered as one session, focusing on molecular models and VSEPR theory, although they were delivered in two separate 1-h sessions. The other session, dedicated to the periodic table and periodic properties, was carried out in two consecutive 2-h sessions.

The methodology begins with a description of the objectives of the seminar/workshop. Next, the students

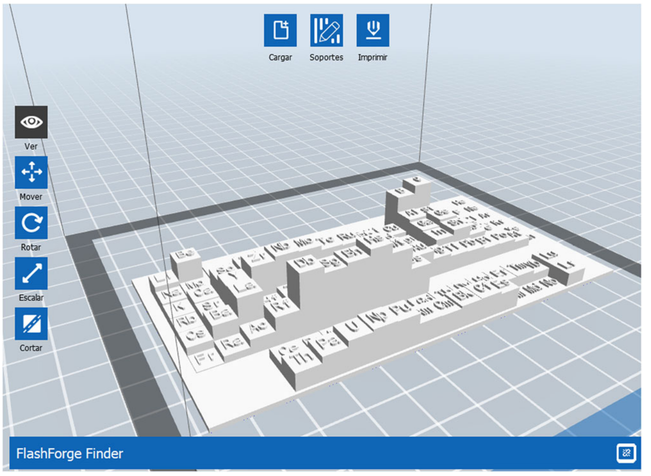

FIGURE 2 Model of the periodic system based on atomic density used by the three-dimensional group.

complete a questionnaire using the Socrative application [17] containing content related to the thematic block covered in the seminar, to assess their prior knowledge. Then, the professor gives a theoretical explanation through a lecture on the topics to be covered, followed by the practical part.

During the practical part, while the professor guides the students in using the software and carrying out the required tasks, the students themselves engage in modelling. Since this was a pilot experience with limited teaching hours, pre-existing models of both molecular structures and the periodic table with periodic properties were used, depending on the specific topic. Therefore, the students could only edit the models in terms of size, shape, or combining multiple models.

Figures 2 and 3 show, as an example, a model of the periodic system and its printed form, which the students worked with in one of the workshops.

In this way, the influence on the three sections of the final examination of the subject was assessed: formulation and nomenclature (10% of the final examination grade), theoretical and practical questions on the

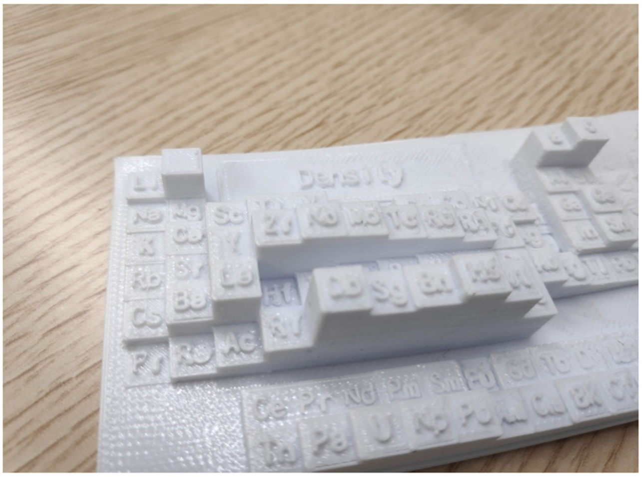

FIGURE 3 Three-dimensional (3D) printing of the periodic table based on atomic density used by the 3D group.

structure of matter (40%), reactivity and stoichiometry problems (50%), and on the final grade.

2.2.4 | Likert scale

Various statistical tests were used to investigate the influence of the 3D printing technology on the grades and motivation of our students. The Wilcoxon signed-rank test was used to assess differences in median grades, and the Friedman and Nemenyi tests were used to assess differences in the different scores. A significance level of $\alpha = .05$ was used for all tests.

A satisfaction questionnaire was given to the students to understand what they thought about this innovative methodology and the use of the 3D printing technology. They had to answer the questions by assigning a number to each of questions. The analysis of the results has been carried out qualitatively.

- 1 means strongly disagree;
- 2 means somewhat disagree;
- 3 means somewhat agree;
- 4 means strongly agree.

3 | RESULTS AND DISCUSSION

3.1 | Teaching experience and evaluation of the intervention

- The experience with the students has been very positive. The students quickly adapted to using both the printer application (FlashPrint) and the FlashForge printer itself. In the case of the software, the students were able to use it with little or no explanation from the teachers. Both students and teachers had access to the tutorials available on the FlashForge website and the printer manuals. Overall, the feedback on the prints from the implemented teaching intervention was very positive. However, there are two points that could be improved in future courses using this methodology. The first is to increase the number of hours devoted to this type of methodology. A total of 4 h, divided into two 1-h seminars and a 2-h laboratory workshop, is not enough to make full use of 3D technology. In addition, the lack of materials, despite the fact that there are enough materials for printing, but only one printer, has hindered its regular use during the sessions and has resulted in a high workload outside of class time. Therefore, and to solve these problems in the implementation of this methodology, two possible solutions are proposed:
- Increase the number of hours for the use and learning of modelling, since the time used in this study is apparently insufficient.
- It would be necessary to reduce the size of the student groups or increase the number of 3D printers so that the time needed to print the models would be less limiting. Also, the size of the models could be reduced, higher-speed printers could be used or no teaching hours could be used for printing.

3.2 | Impact on students

The impact of the teaching intervention on student learning has been evaluated in two ways. First, by comparing the results between the first and second questionnaires. The assessment of learning in the class is based on the results of the initial and final questionnaires for the teaching practice. As shown in Figure 4, the results were classified into models of lower (Model E) to higher complexity (Model A), grouped by percentage of responses, and represented in the form of learning stairs [17]. Table 2, as an example, displays the results obtained for a specific set of seminars in the 3D group ($N_{\mathrm{i}} = 11$ out of a total $N_{3\mathrm{D}} = 67$ students) in terms of the initial and final questionnaires for the first seminar. The levels of learning are indicated using symbols to denote whether they have decreased from the initial questionnaire to the final one (−), remained at the same level (=) or increased (+).

It can be observed that, in general, students show limited knowledge at the beginning of the class on the subject to be taught, with a majority of students in levels D and E, comprising approximately 72%. This highlights the low level of prior knowledge in this subject among engineering degree students. However, there is an increased level of subject knowledge at the end of the

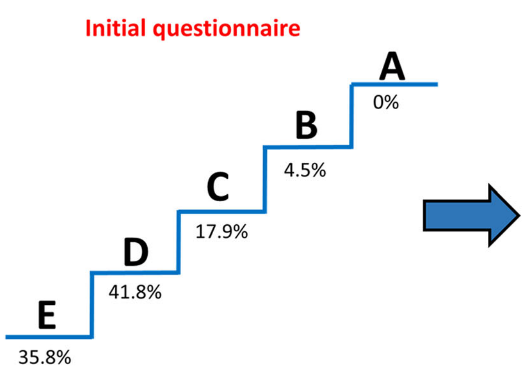

FIGURE 4 Grouping according to knowledge models and results of the initial and final questionnaire for the first questionnaire and for all participating students.

TABLE 2 Distribution of results according to levels of learning for students in a class of the three-dimensional group of seminars, comparing the initial and final models for the first and second seminars on molecular models.

Student	Pretest	Posttest	Evolution
1	C	C	=
2	D	C	+
3	D	C	+
4	E	C	+
5	C	B	+
6	D	C	+
7	E	B	+
8	D	B	+
9	C	A	+
10	E	D	+
11	D	B	+

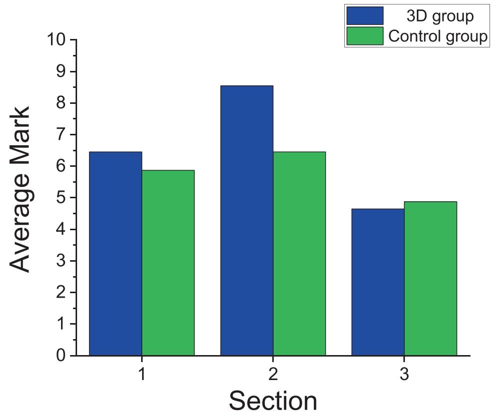

FIGURE 5 Average marks for the different sections of the final exam and the final scores of the students in the three-dimensional and control groups: (1) formulation and nomenclature, (2) theoretical and practical questions on the structure of matter and (3) reactivity and stoichiometry problems.

class compared to the beginning. The percentage of students in levels E and D decreases from 72% to 9%, and at least one level improvement and thus an increase in the grade is observed in 91% of the students in the group. It is worth noting that no student has declined in any level. Therefore, it can be considered that the students have undergone a learning process throughout the class that has allowed them to enhance their knowledge.

It is important to emphasize that thanks to the use of the Socrative application, these pretest and posttest assessments can be carried out quickly and easily, providing immediate results that enable the evaluation of the learning process and the modification of concepts to focus on for better student learning within the same session.

Figure 4 illustrates, as an example, the overall results of all the students in the 3D group for the initial and final questionnaires corresponding to the first seminar, classified according to levels of learning. A significant improvement in the acquired knowledge by the students is clearly observed. While the predominant model in the initial questionnaire is D, in the second case, it is C. Additionally, models A, B, and C (above the passing score in the exam) increase from 22.4% to 70.2%. Consequently, the number of students with failing grades (levels E and D) decreases from 77.6% to 20.8%. It is also noteworthy that the percentage of students in levels B and A, which correspond to grades of 'good' and 'excellent', increases from 4.5% to 25.4%, more than fivefold.

The average scores for the different sections of the final exam and the final scores of the students in the 3D and control groups are shown in Figure 5 and were analysed by Friedman and Nemenyi tests. There was a significant improvement in the scores in the theoretical and practical questions on the structure of matter of the 3D group compared to the control group, proving that the use of this technology in the classroom can improve behaviour related to this topic. The other two sections do not show a significant change, so that on the one hand the grades do not improve as expected since the use of 3D technology does not address

TABLE 3 Average marks of the quantitative questions of the opinion questionnaire.

Question	Average mark	
	3D Group	Control Group
The use of 3D printing technology has increased my interest and motivation for the course.	3.54	-
My involvement in the use of this tool has been appropriated.	3.78	-
I am satisfied with the results I have obtained after using 3D printing in molecules modelling.	3.25	-
I am satisfied with the results I have obtained after using 3D printing to study periodic properties.	2.89	-
I would like that other courses during my degree use this 3D technology.	3.54	-
I have enjoyed General Chemistry course.	3.09	2.51

these topics, but the grades are not worsened by taking teaching hours away from these topics, especially formulation and nomenclature (see Table 1). Finally, the average grade of the students was not significantly affected.

A satisfaction questionnaire was completed by the students at the end of the General Chemistry course. Table 3 shows the results as average scores for each question in the survey. In general, 3D printing was rated very positively by the STEM students, especially for the study of molecules. They also emphasised that the use of the 3D technology increased their motivation. In addition, the students thought that this technology could be used in other courses. Finally, comparing both groups of students, it is clear that the students who have used the 3D printer to study molecules and periodic properties have enjoyed the subject of General Chemistry more than those in the control group.

4 | CONCLUSIONS

In this work, an initiative has been proposed that includes the use of 3D technology for teaching two thematic blocks (molecular structures and periodic properties) in seminars and laboratory workshops of the General Chemistry course in various STEM degrees of the University of Seville. The feedback from both teachers and students also supports the idea that the use of this technology improves motivational and learning aspects for students, although substantial improvements are necessary for its implementation in the course's teaching project. The use of initial and final questionnaires has allowed us to demonstrate, through the substantial improvement in the results of the tests administered after the classes, that there is a considerable increase in the level of knowledge throughout the course. The results of Friedman's test proved that there were statistical differences between the theoretical and practical questions on the structure of matter scores obtained. The results of the Nemenyi test showed that only the knowledge of the structure of matter was improved by using 3D printing technology. Results obtained by the satisfaction questionnaire show that it is a good idea to implement 3D printing as an information and communication technology in the STEM classroom.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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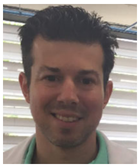
REFERENCES

1. G. E. Adams, *Nonconventional methods in teaching matter, atoms, molecules & the periodic table for nonmajor students*, Am. Biol. Teach. **59** (1997), no. 7, 428–438.
2. B. Berman, *3-D printing: the new industrial revolution*, Bus. Horiz. **55** (2012), no. 2, 155–162.
3. V. D. B. Bonifácio, *QR-coded audio periodic table of the elements: a mobile-learning tool*, J. Chem. Educ. **89** (2012), no. 4, 552–554.
4. G. C. Brumlik, *Molecular models featuring molecular orbitals*, J. Chem. Educ. **38** (1961), no. 10, 502.
5. C. E. Copolo and P. B. Hounshell, *Using three-dimensional models to teach molecular structures in high school chemistry*, J. Sci. Educ. Technol. **4** (1995), no. 4, 295–305.

6. H. Coskun Karabulut, N. Elcan Kaynak, and I. A. Kariper, *Preservice teachers' engagement with stem-based hands-on activities in online chemistry laboratory courses*, Res. Sci. Technol. Educ. (2023), 1–21.
7. H. Coşkun, B. Akarsu, and İ. A. Kariper, *The effects of educational games based on science stories on students' academic achievements in science and technology classroom*, Ahi Evran Univer. J. Kırşehir Educ. Faculty **13** (2012), no. 1, 93–109.
8. S. C. Crane and R. S. H. Liu, *Models for demonstrating organic structures to a large audience*, J. Chem. Educ. **63** (1986), no. 6, 516.
9. B. Gross, S. Y. Lockwood, and D. M. Spence, *Recent advances in analytical chemistry by 3D printing*, Anal. Chem. **89** (2016), no. 1, 57–70.
10. Y. He, Y. Wu, J. Fu, Q. Gao, and J. Qiu, *Developments of 3D printing microfluidics and applications in chemistry and biology: a review*, Electroanalysis **28** (2016), no. 8, 1658–1678.
11. A. Hoffman and M. Hennessy, *The people periodic table: A framework for engaging introductory chemistry students*, J. Chem. Educ. **95** (2018), no. 2, 281–285.
12. K. G. Larson, G. R. Long, and M. W. Briggs, *Periodic properties and inquiry: student mental models observed during a periodic table puzzle activity*, J. Chem. Educ. **89** (2012), no. 12, 1491–1498.
13. B. M. McCollum, L. Regier, J. Leong, S. Simpson, and S. Sterner, *The effects of using touch-screen devices on students' molecular visualization and representational competence skills*, J. Chem. Educ. **91** (2014), no. 11, 1810–1817.
14. S. C. Nwafor, F. N. Ibe, and N. M. Muoneke, *Optimizing information and communication technology applications in chemistry learning*, J. Res. Instr.**2** (2022), no. 2, 151–162.
15. J. Pernaa and S. Wiedmer, *A systematic review of 3D printing in chemistry education–analysis of earlier research and educational use through technological pedagogical content knowledge framework*, Chem. Teach. Int. **2** (2019), no. 2, 20190005.
16. A. E. Saieed, *Homemade models of the five d-atomic orbitals*, J. Chem. Educ. **57** (1980), no. 11, 805.
17. J. Santos, L. Parody, M. Ceballos, M. C. Alfaro, and L. A. Trujillo-Cayado, *Effectiveness of mobile devices as audience response systems in the chemistry laboratory classroom*, Comput. Appl. Eng. Educ. **27** (2019), no. 3, 572–579.
18. M. Stieff, M. Ryu, B. Dixon, and M. Hegarty, *The role of spatial ability and strategy preference for spatial problem solving in organic chemistry*, J. Chem. Educ. **89** (2012), no. 7, 854–859.
19. B. Berté, M. West, and C. Duncan, *For Mastery Connect, [consultado 20 Oct 2014]*. http://socrative.com/index.php, 2014.

AUTHOR BIOGRAPHIES



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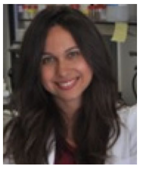

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