Problem-solving skills: some post-pandemic effects

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Abstract

The development of problem-solving skills is one of the main goals of education. These skills are part of the components of critical thinking. In science and engineering, it is considered important to promote those skills that help students develop flexible cognitive strategies that prepare them to face and analyze unexpected situations in their professional life, to find meaningful solutions. Multiple theoretical frameworks have been developed about the problem-solving process from different perspectives, however, the impact of these on the pedagogical practice of universities is very small. These are complex skills that include various cognitive components, such as knowledge domain and structure, metacognitive skills, motivational and attitudinal components, the belief system, etc. It is very common that the teaching of these skills is limited to the use of techniques and skills to solve exercises rather than problems. A problem must pose a new situation in which the student must identify the conditions to apply the related concepts and principles, plan, and make decisions. The health emergency caused changes in pedagogical practices; teachers had to design strategies that offered opportunities for more autonomous work to the students. With the return to the face-to-face modality, interest has arisen in evaluating the skills of students who previously worked in the virtual mode and who must now adapt to the face-to-face mode. The purpose of this study was to compare the achievements regarding the application of problem-solving skills at the third level, that is, those that imply the application of concepts and principles to new situations, in the context of a general chemistry course at a Peruvian university. Three groups were compared: students who took the course before the pandemic, virtual mode students, and students who took the course after the pandemic in face-to-face mode. The results showed that the first two groups had similar achievements, while the third group had a higher level of achievement that differed significantly from the previous two. It could be understood that the previous experience in the virtual mode fostered the development of self-learning skills that have had a positive effect on the problem-solving skills.

Keywords: *Problem-solving skills, science education, remote teaching, higher education*

1. Introduction

According to Saiz [1], the ability to solve problems is the most inclusive of all those that are part of the components of critical thinking. According to the author, people usually act with the purpose of achieving goals or solving problems and, for this, we make use of a set of reasoning and decision-making skills. In this way, when the problematic situation is solved effectively, it means that it has been thought critically.

For several decades, university education has recognized the need to direct its pedagogical models towards the training of professionals who have the capacity to face problematic situations, both within their discipline and in interdisciplinary spaces, in an efficient, creative, and innovative manner and, therefore, it is essential to promote the development of skills for solving complex problems.

Multiple theoretical frameworks for problem-solving skills have been reported from different conceptions of learning, however, the most addressed proposals come from cognitive or sociocultural science or information processing. Constructivism recognizes the dependency between the resolution process and the content in which the problem is contextualized [2].

Components shared by the different proposed models can be identified, which include the specific domain knowledge that the subject that solves problems must have and which involves factual, conceptual, and procedural knowledge. This knowledge is characterized by being adequate, organized, accessible and integrated. A second component is heuristics, or the use of general strategies to address non-routine or familiar problems. Self-regulation and control skills are also part of the components considered in problem-solving models, as well as belief systems and affect [3], [4].

These components are incorporated into a model proposed by Sugrue [3] in which critical variables of the problem-solving process are considered and that can be improved through educational intervention. The model assumes that the ability to solve problems, in a particular domain, results from the complex interaction of three cognitive constructs: knowledge structure, cognitive functions (planning and monitoring), and beliefs (perceived self-efficacy, task demands, and the attraction of the task).

In science education, the development of problem-solving skills is essential since it is considered one of the main resources to consolidate and promote scientific knowledge. However, it is common that in pedagogical practice the development of exercises is prioritized over problem solving. A problem must pose a new situation, preferably open, in which different ways of solution can be considered. An exercise is a routine situation whose solution involves the application of known procedures [4], [5].

The Knowledge Structure construct of the Sugrue model defines three levels, the first two related to the identification of concepts and the application of principles. The third level is related to the link of the concepts and principles to the conditions and procedures that can be applied when facing a new problematic situation. This level allows identifying the greatest achievement in the development of problem-solving skills.

In recent years, higher education had to adopt remote teaching modalities due to the health emergency. This implied the design of strategies and resources that favored the abilities for autonomous learning of the students. When returning to the face-to-face modality, interest arises in evaluating possible differences in the use of problem-solving skills in the third level of the knowledge structure of the Sugrue model. The purpose of this study was to compare the level of achievement in these skills of three groups of students in a General Chemistry course at a Peruvian university, the first took the course face-to-face before the pandemic, the second did so during the pandemic, in virtual mode, and the third, in face-to-face mode after the pandemic.

2. Methodology

2.1 Participants

The participants in this study were three groups of first-year science and engineering students from a Peruvian university. They were enrolled in the second General Chemistry course of their curriculum. The characteristics of the groups are shown in Table 1:

Table 1. Participants characteristics

Group	Enrolled in Chem 2	Teaching modality	Age	Gender	
				Male (%)	Female (%)
1 (N = 36)	Before the pandemic	face-to-face	17 - 21	66,7	33,3
2 (N = 36)	During the pandemic	virtual	17 - 20	55,6	44,4
3 (N = 36)	After the pandemic	face-to-face	17 - 20	52,8	47,2

2.2 Context of the study

Face-to-face mode: the organization of the course included a weekly class session to present the topic and activities that the student had to carry out such as tasks in which exercises corresponding to the first two levels of the Sugrue model were proposed. The evaluation considered weekly tests in which a question located in the third level of the Sugrue model was posed and that corresponded to 20% of the total score.

Virtual mode: the organization of the course included a weekly session via Zoom to present the topic, the video of this session was available for students to access when they considered it necessary. A series of learning activities and formative assessments were designed as resources for learning. The students' performance was permanently monitored by the professor and teaching assistants. The evaluation was like the face-to-face modality.

2.3 Assessment of third level of knowledge structure

In each weekly test, the percentage of achievement in the question posed according to the third level of the Sugrue model was determined. Then the average obtained at the end of the course was calculated. To verify the differences between the groups, the analysis of variance (ANOVA) was used, considering as dependent variable the average obtained in the third level of knowledge structure, and as independent variable the participant group.
The data were analyzed using Statistical Package for the Social Sciences (SPSS) 23 software ®. The level alpha was established a priori in 0,05.

3. Results

Table 2 shows the descriptive statistics for the percentage of achievement in the third level of knowledge structure of each of the participating groups.

Table 2. Descriptive statistics for % of achievement in the third level of knowledge structure

Group	M	SD	Minimum	Maximum
1	65,128	12,1519	45,0	93,8
2	67,567	9,2512	47,5	82,5
3	80,719	8,8027	65,0	95,0

The ANOVA analysis showed significant differences between the groups ($F (2, 105) = 24,447$; $p < 0,001$). The Tukey B post hoc test revealed significant differences between the group 3 and the other two.
The students in the group that showed the best performance in the use of their problem-solving skills had at least one semester of virtual work. This implied that they had opportunities to develop their skills for autonomous learning, that is, in terms of their organization to manage their learning process to a certain extent, in terms of flexibility to be able to test different solution alternatives that could be discussed with their peers and with facilitators (teacher and teaching assistants), which contributed to the development of their cognitive autonomy. It is evident that this previous experience had a positive effect on the performance shown in the return to face-to-face.

4. Conclusions

The teaching of problem-solving skills is a complex task, since it involves a series of factors related to the characteristics of the students, the context in which the process takes place, the pedagogical resources used, among the most important. A much-discussed critical aspect is the design of the problems that students must address. These should present novel situations of interest to students, so that they learn to apply their abilities to develop strategies that include procedures and concepts selected for their relevance, and that allow them to build a robust and sustained solution. However, this goes hand in hand with the opportunity for students to have a certain level of autonomy in their learning process.
In this study, evidence has been shown that the drastic change in teaching modalities, adapted to a greater or lesser extent to virtuality due to the health emergency, had positive effects when it promoted the development of students' cognitive autonomy. This also contributes to the level of achievement in the application of problem-solving skills.
The return to face-to-face modality must imply a thoughtful redesign of strategies that allow for better achievements in the formation of desirable profiles for the new professionals of the 21st century. The need for change in pedagogical models has been recognized for several years, however, the process has not occurred with the desired speed in university institutions. Perhaps the critical situation in which we have been recently can become an opportunity for reflection and positive change in our pedagogical models.

References

[1] Saiz, C. “Pensamiento crítico y eficacia”, Madrid, Ediciones Pirámide, 2020, 20-34.

[2] Oviedo, P. E. “La resolución de problemas. Una estrategia para aprender a aprender”, Revista de la Universidad de La Salle, 2006, (41), 31-39.
[3] Sugrue, B. “A theory-based framework for assessing domain-specific problem-solving ability”, Educational Measurement: Issues and Practice, 1995, 14(3), 29-36.
[4] Pozo, J. I., Pérez, M., Domínguez, J., Gómez, M. A., Postigo, Y. “La solución de problemas”, Madrid, Editorial Santillana, 1994.
[5] Pozo, J. I., Postigo, Y., Gómez, M. A. “Aprendizaje de estrategias para la solución de problemas en ciencias”, Alambique: Didáctica de las Ciencias Experimentales 5, 1995, 16-26.