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A digital game to teach stellar nucleosynthesis: design and student feedback

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The use of digital technologies combined with an interdisciplinary approach that connects the periodic table to astronomy can provide students with a better understanding of the stellar nucleosynthesis of chemical elements, and thus motivate them to study these subjects. This work presents an educational digital game entitled "The Periodic Table According to Cosmochemistry", developed to playfully approach the synthesis of chemical elements in the context of astronomy.

At the beginning of the first phase, the player should capture a proton and throw it towards another one to produce a deuteron, a positron and a neutrino. Next task is to capture a deuteron and throw it towards a proton to synthesize a helium-3 nucleus. Each time a new chemical element is synthesized, the player sees a drawing with a brief description of that element, which is then placed on a periodic table. This phase ends when the player synthesizes the other elements of the proton-proton chain: lithium, beryllium and boron. In the second phase, the player goes through the triple-alpha process, the CNO cycle and the carbon-burning process. Finally, the last phase corresponds to a supernova explosion, in which heavier elements are synthesized.

Written in Python, the game is currently available in English and Portuguese (Siqueira, 2023) and can be freely downloaded from https://sites.google.com/site/credianafaria/. In order to evaluate the effectiveness of the game, we conducted teaching sessions at different school levels to investigate students' learning and perception about the game. These sessions involved 52 students, which were enrolled at an elementary school (12 students), a high school (8 students) and a university (32 students). In each session, students answered a questionnaire containing open and multiple-choice questions, played the game and answered the questionnaire again. The answers were then analyzed qualitatively and quantitatively, so that we could compare the answers before and after playing the game.

Table 1. Undergraduate students' feedback

Component	N	N_i
Motivation	11	2
User experience	17	9
Learning	3	2

The undergraduates also answered a questionnaire adapted from an educational game evaluation model developed by Savi et al. (2011), which consists of 3 subcomponents (motivation, user experience and learning), comprising 15 dimensions, 29 standard items and 3 customized items. The learning subcomponent includes customized items, which address the first three levels of Bloom's revised taxonomy: remember, understand and apply (Anderson & Krathwohl, 2001). The feedback pointed out the strengths and weaknesses of the current version of the game and provided suggestions for future improvement. A summary of the results can be found in Table 1, which shows each subcomponent, the total number of items N and the number of items that need to be improved N_i.

The qualitative and quantitative results provided evidence that this game is an effective educational resource, capable of motivating students, promoting learning, and providing a positive gaming experience. The use of educational digital games, such as this one, can be a promising approach to improve the teaching of stellar nucleosynthesis and the origin of the chemical elements. By integrating astronomy, chemistry, nuclear physics, and digital technologies, educators have the opportunity to spark students' interest and encourage their pursuit of knowledge in a meaningful way.

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