In this work, a holistic methodology was developed and implemented in a computer-aided framework with the purpose of establishing a pedagogical simulation tool for bioprocess applications. The methodology integrates the development of a process simulator with the use of gamification elements to improve the pedagogical experience. Moreover, model development and reuse was incorporated into the framework through creating a generic model template. The application of the methodology was demonstrated by the simulation of a batch fermentation process of Saccharomyces cerevisiae cultivated under aerobic conditions with glucose as substrate, thereby, demonstrating mixed metabolism dynamics and considering the inhibition of ethanol consumption due to the presence of glucose with an integrated learning design and gamification elements. The learning experience, done with beta users with different previous levels of knowledge about fermentation processes, confirmed an interest for using gamification for training chemical engineering, biochemical engineering, and biotechnology students.