PHARMAVIRTUA: educational software for teaching and learning basic pharmacology

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INFORMATION AND COMMUNICATION TECHNOLOGIES have become important tools for teaching scientific subjects such as anatomy and histology as well as other, non-descriptive subjects like physiology and pharmacology (8–10). Software has been used to facilitate the learning of specific concepts at the cellular and molecular levels in the biological and health sciences (3, 11, 15). Although educational software, virtual environments, and e-learning are not new, their scope has been expanding to reach the more complex areas of science and higher levels of education. As a case in point, the British Pharmacological Society (6) offers access to >250 different software packages, not to mention what can be found by searching other databases such as Google, Google Scholar, or ERIC. With so many different programs available, there is a clear need for more rigorous research to provide a scientific and pedagogical foundation for the general content and usability of this software, focusing on an empirical rather than a descriptive software evaluation. Despite the wealth of pharmacology software found on the web, few of these programs are evaluated pedagogically. Developing educational software is quite different from developing non-educational software, such as business applications. Educational software should be designed to facilitate learning for its users, who may not already possess the knowledge being studied (7). In this context, our group developed “PHARMAVIRTUA,” a Creative Commons-licensed software package, to help pharmacology teachers by promoting an active and motivated learning environment for students.

The present study evaluated the usefulness of the PHARMAVIRTUA educational software package for teaching and learning basic pharmacology. We analyzed subjective (student perception) and objective (student exam results) parameters as well as navigability, usability, friendliness, and other characteristics of the software.

METHODS

Software Development

PHARMAVIRTUA was developed using a combination of Adobe Director and Adobe Flash software. The software runs in a Microsoft Windows environment. The software was distributed freely on CD-ROM and can be downloaded from http://www.lcc.kfoux.com/imuno/pharmacology.html as a compacted executable file.

Teachers and researchers within the field of pharmacology developed PHARMAVIRTUA with a focus on pharmacokinetics and pharmacodynamics, which they considered to be fundamental concepts in pharmacology. Currently available pharmacology software uses six major components: quizzes, electronic books, tutorials, simulations, animations, video material, and electronic learning environments (6). PHARMAVIRTUA, like many other programs, contains more than one of these components. Basic pharmacology content is presented in tutorial form (using hypertext and static figures); important pharmacological phenomena are presented as animations and simulations. The whole project was developed using hypermedia concepts, with the use of auditory feedback, animations, and hypertext.

Students can install the software or run it directly from a CD or flash drive. After the executable file is launched by double-clicking on it, an initial screen is shown with the following main topics displayed on the lefthand side: Routes of Administration, Pharmacokinetics, and Pharmacodynamics. Help and Exit buttons are located on the bottom left of the screen along with a link to Contacts and the Bibliography.

Educational and software characteristics were integrated and validated using a cross-functional software design life cycle, modified for pedagogical purposes. Each content module was analyzed with questionnaires about usability and educational issues for both students (Table 1) and teachers (100% agreed that the software was a helpful tool for teaching pharmacology).

Educational Aspects and Final Evaluation

PHARMAVIRTUA was evaluated by a total of 60 students who participated in the course titled “Pharmacology: an Integrated Approach.” The interdisciplinary course, supported by the Oswaldo Cruz Institute (FIOCRUZ, Rio de Janeiro, Brazil), was taught in 2011 and repeated in 2012. It covered the basic principles of pharmacology (pharmacokinetics and pharmacodynamics). A total of 34 students were recruited in 2011, and 26 students were recruited in 2012. Each summer course was taught over 1 wk, with a workload of 45 h. Five pharmacology teachers were directly involved with the course. Study participation was voluntary; all participants signed the Free Informed Consent form.

Inclusion criteria were as follows: undergraduate students from the biological and health fields who had a general grade point average of >7.0 on a scale of 1–10, with 10 being the highest grade.

On the first day of class, all students performed a pretest with 10 questions about basic pharmacology subjects. Each day during the course week, there were two pedagogical objectives: a lecture with case discussions (in which all students participated) and a period planned for students to study previously discussed material using either the software (software group) or using other tools, including textbooks, student notes, or Internet content but not including the software (nonsoftware group). These two periods were equally distributed throughout the total course load. Participants were randomly divided into two groups. The nonsoftware group participated in all activities except use of the software (n = 20), whereas the software group participated in all activities and used PHARMAVIRTUA software (n = 40).
Table 1. Likert-type rating scale to evaluate student perceptions of learning characteristics and the usefulness of the software as a pedagogical tool

<table>
<thead>
<tr>
<th>Statements</th>
<th>Score</th>
</tr>
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<tbody>
<tr>
<td>Use of the software stimulates logical thinking.</td>
<td>4.0 ± 0.72</td>
</tr>
<tr>
<td>A pharmacology textbook and a teacher are also necessary.</td>
<td>4.23 ± 1.12</td>
</tr>
<tr>
<td>A pharmacology textbook is also necessary.</td>
<td>4.3 ± 0.46</td>
</tr>
<tr>
<td>The software is sufficient for learning pharmacology. A textbook is not necessary.</td>
<td>2.8 ± 0.88</td>
</tr>
<tr>
<td>The software is a helpful tool for learning pharmacology.</td>
<td>4.8 ± 0.41</td>
</tr>
<tr>
<td>In general, the content is up to date.</td>
<td>4.15 ± 0.48</td>
</tr>
<tr>
<td>The overall content is satisfactory. It is logically organized.</td>
<td>4.7 ± 0.56</td>
</tr>
<tr>
<td>In general, the software organization is clear.</td>
<td>4.75 ± 0.44</td>
</tr>
<tr>
<td>The software navigation is easy and intuitive.</td>
<td>4.88 ± 0.33</td>
</tr>
</tbody>
</table>

Values are means ± SD; n = 40 students. Statements were evaluate according to a Likert-type rating scale of 1–5 as follows: 1 = strongly disagree, 2 = disagree, 3 = neither disagree nor agree, 4 = agree, and 5 = strongly agree.

At the end of each course, all students performed a posttest.

Pre- and Posttests

The pretest/posttest research design was used to assess the students’ learning. A test is applied before the beginning of the educational intervention and again afterward to look for changes in students’ scores. The pretest/posttest research design was performed according to Slater and colleagues (12). This approach is based on the process-product notion: if one applies an educational process to learners, then the end product of enhanced learning achievement or attitudes can be measured and compared with the initial condition. The measure is expressed as student or sample gain, calculated as follows: sample gain = \( X_{\text{post}} - X_{\text{pre}} \), where \( X_{\text{post}} \) and \( X_{\text{pre}} \) are the mean of the posttest and the mean of the pretest scores, respectively.

Each test (pretest and posttest) contained 10 questions about basic pharmacology topics divided equally among 3 cognitive levels (2). Tests were randomly created from our database, which contains >500 questions. In addition, we recorded the time that each student took to complete the exam.

Pre- and Posttest Validation

To verify the difficulty level of each test, we administered it to five volunteer pharmacy students. Each student performed the two tests (pre- and posttests) immediately after the other. No statistical difference was recorded between the number of correct answers on the pretest and on the posttest. Thus, any possible differences between pre- and posttest grades are not related to differences in the difficulty level of the two tests.

Subjective and Qualitative Analysis

Users completed a questionnaire composed of affirmative statements with answers in the form of a Likert-type rating scale to evaluate student perceptions of learning characteristics and the usefulness of PHARMAVIRTUA as a pedagogical tool. Questions about the usability of the software were also included. Students were requested to strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree with the statements on the questionnaire.

To perform a qualitative analysis, we recorded the users’ opinions, suggestions, and criticisms.

Statistical Analysis

To test whether the samples came from a Gaussian distribution, we used an appropriate parametric test; if not, we used an appropriate nonparametric test. The tests used are specified in Fig. 1 and were two-tailed and paired. Data are reported as means ± SD.

Differences were considered significant at the \( P < 0.05 \) level.

RESULTS

At the time of their participation in the summer courses, all students were officially enrolled in a public Brazilian university in undergraduate degree programs in either medicine, pharmacy, or biomedical science. No socioeconomic differences were found between groups (data not shown). Of the 60 students who participated in the 2 summer courses, 42 students were women and 18 students were men. Their average age was 21 ± 2 yr.

Objective Analysis (Pre- and Posttests)

Overall scores increased after the course for both the test and control groups (Fig. 1). For the nonsoftware group (n = 20), the average pretest score was 3.7 ± 0.2; for the software group (n = 40), the average pretest score was 4.0 ± 0.24. The average posttest score was 4.95 ± 0.24 for the nonsoftware group and 6.47 ± 0.23 for the software group. The difference between the pre- and posttest scores was statistically significant (\( P < 0.001 \)) for both the nonsoftware and software groups.

Use of the software was associated with better exam performance. Pretest grades showed that the background knowledge of the groups was similar, a fact not reflected in the posttest grades.

With regard to the sample gain, there was an overall improvement in scores on the posttest compared with the pretest. The sample gain was higher for the software group than for the nonsoftware group. The difference between pre- and posttest scores was calculated as described in METHODS. A Wilcoxon matched-pairs signed rank test (two-tailed) showed that the difference was significant with \( P < 0.0001 \) (data not shown).

Fig. 1. Box plot with pre- and posttest scores for both groups of students. NS, students in the nonsoftware group who participated in the course and did not use PHARMAVIRTUA (n = 20); S, students in the software group who participated in the course and used PHARMAVIRTUA (n = 40). The dashed line represents the minimum passing grade. * \( P < 0.001 \) by ANOVA followed by a Tukey test.
There was an overall reduction in test completion time from the pretest to the posttest. Pretest times averaged 28 ± 8 min for the nonsoftware group and 35 ± 9.5 for the software group. Posttest times were similar for the two groups, averaging 15 ± 6 min for the nonsoftware group and 15 ± 2 min for the software group.

Subjective Analysis

The results of the questionnaire ranking student perceptions of the software regarding learning perception, pharmacological content, and software usability on a Likert-type rating scale are shown in Table 1. The learning perception statements look for improvement in logical thinking, dependence on a pharmacology textbook or teachers, and use of the software to reach pedagogical objectives.

The overall content and software organization were considered satisfactory by the majority of students; a significant number of students either strongly agreed or agreed that the software was clearly presented and its content was up to date (Table 1). All students strongly agreed or agreed that the software navigation was easy and intuitive (usability).

Several comments were written regarding the organizational characteristics of the software and educational factors. Some of these user observations are given below.

Positive points. Positive observations from some users were as follows:

User 1: “Very instructive and stimulating.”
User 2: “Animations are so didactic.”
User 3: “Helps to visualize the pharmacological concepts.”
User 6: “Good texts and links that trigger all the issues with illustration and animations.”
User 7: “The animations are excellent.”
User 8: “The simulations are interesting and important.”
User 9: “Clear and simple.”
User 14: “It’s very interactive and stimulates curiosity.”
User 17: “Makes learning more dynamic and interactive. It’s very intuitive.”

Negative points. Negative observations from some users were as follows:

User 3: “Some issues are superficial.”
User 4: “The legends could be more clear.”
User 6: “The software is good however its approach is basic.”
User 7: “Even with a basic approach, the issues are superficial.”

Note that these minor negative points have either been considered or improved upon. In addition, there is a link to receive user comments on the site where the program can be downloaded. Therefore, the software can be constantly improved based on user feedback.

DISCUSSION

Descriptive Analysis

PHARMAVIRTUA software was developed by faculty and researchers. Its pedagogical impact was evaluated using students’ performance and perception as end points. This software is designed specifically to be used in an integrated health curriculum or even in a constructivist approach. All pharmacology content explored in this software was gradually presented, allowing contact and integration with crucial concepts in physical chemistry, biochemistry, biophysics, physiology, and other fields. Thus, PHARMAVIRTUA software was planned to be an interdisciplinary pedagogic tool using graphics, animations, and simulations. The software is flexible to accommodate a great variety of students with different levels of background knowledge and different learning styles.

Studies have demonstrated that multimedia resources, such as computer dynamic simulations and educational software, have been very successfully applied in the teaching-learning process. They have been shown to increase interest and improve the understanding of concepts related to areas such as genetics, biochemistry, molecular biology, and immunology (1, 4, 13, 14). However, software evaluation is a formal procedure that uses three different techniques (5). The first technique is based on experimental methods, using pre- and posttests with experimental and control groups to assess the effectiveness of a piece of software. The second technique is a checklist approach based on applying a set of predetermined criteria to a piece of software. The third technique is a qualitative evaluation of the software.

Here, we used experimental and qualitative methods to evaluate the software. Although the overall scores increased after the course for all students, the group that used the software showed a greater improvement. When sample gain was compared between the groups, the best results were obtained by students who used PHARMAVIRTUA. There was no significant difference between the groups in the time needed to complete the pre- and posttest, meaning that the software group improved their scores without requiring additional time to complete the test. These results imply that software use may have improved integration or contextualization of information, so that students were able to recall information more easily. We also compared perception results with the empirical data obtained using the pre- and posttests. All qualitative measures showed positive outcomes, reinforcing the conclusion that the new educational environment created by the use of these technologies can motivate students and teachers, which results in positive perceptions (as depicted in the majority of the statements analyzed).

As mentioned, PHARMAVIRTUA was not developed to be used alone, replacing textbooks and teachers. Rather, it was designed as a complementary tool for teaching and learning pharmacology. A significant number of students strongly agreed or agreed with the idea that a textbook or a teacher is necessary to better achieve pedagogical aims regarding the subject of pharmacology (Table 1). However, many students also strongly agreed that PHARMAVIRTUA software was a helpful tool to learn pharmacology.

Most of the students strongly agreed or agreed that the use of the software stimulated logical thinking. All aspects of software engineering were also considered, and significant advantages were observed (Table 1).

In conclusion, we believe that PHARMAVIRTUA is a program that can truly benefit teachers and students in the study of pharmacology by assisting with integration and easy recall of principles presented to the university-level student. We believe that the use of animated movies, schemes, and text in diversified and integrated content aided in enhancing the students’ conceptual understanding and application of basic
pharmacology. With better understanding, there is an overall motivation to learn science, specifically the subject of pharmacology, as well as a positive perception of the learning process. With the overwhelming quantity of tools available, it is easy to get lost in programs that have little or no pedagogical value. The value of each program must be demonstrated to ensure that only high-quality tools are incorporated into the educational system. PHARMAVIRTUA is a valuable tool for teaching and learning pharmacology.

DISCLOSURES
No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

REFERENCES