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CONTINUING EDUCATION

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Medication Calculation

The Potential Role of Digital Game-Based Learning in Nurse Education

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Medication dose calculation is one of several medication-related activities that are conducted by nurses daily. However, medication calculation skills appear to be an area of global concern, possibly because of low numeracy skills, test anxiety, low self-confidence, and low self-efficacy among student nurses. Various didactic strategies have been developed for student nurses who still lack basic mathematical competence. However, we suggest that the critical nature of these skills demands the investigation of alternative and/or supplementary didactic approaches to improve medication calculation skills and to reduce failure rates. Digital game-based learning is a possible solution because of the following reasons. First, mathematical drills may improve medication calculation skills. Second, games are known to be useful during nursing education. Finally, mathematical drill games appear to improve the attitudes of students toward mathematics. The aim of this article was to discuss common challenges of medication calculation skills in nurse education, and we highlight the potential role of digital game-based learning in this area.

KEY WORDS

Digital game-based learning • Learning strategies • Medical errors • Medication calculation

Medication-related activities are everyday tasks for nurses, whose duties are diverse and complex. Thus, nurses need to be highly competent in a number of areas, such as the administration of medication, documentation, medication safety, and medication calculations.[1] Moreover, there is an increasing demand for medication competency among nurses because of the focus on medication safety, the increasing number of drugs available, and the fact that more patients are older and tend to have more comorbidities and polypharmacy challenges.[1] Medication errors are frequent, and they may be the most common type of medical error.[1–3] Medication errors include incorrect routes of drug administration, mistiming or omissions, incorrect drugs, and incorrect doses, which are related to various human factors such as misreading, misunderstanding, and stress.[2–4]

Clearly, nurses and student nurses need to be skilled in medication calculation. Medication calculation is only one of several medication-related activities, but it is crucial because it may have critical outcomes for patients.[5] Despite the development of various learning strategies,[6–9] medication calculation appears to be a global educational challenge, possibly because of low numeracy skills[5,10,11] and mathematical anxiety[12,13] among student nurses. Therefore, it is important to investigate alternative or supplementary didactic approaches to medication calculation drills. The aim of this article was to discuss common challenges of medication calculation skills in nurse education, and we emphasize the potential role of digital game-based learning (DGBL) in this area as well as in medication management.

CALCULATION CHALLENGES AND STRATEGIES

The challenges experienced during student nurse medication calculation training are of great concern, and a variety of teaching strategies have been developed to address the needs of students.

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Numeracy Skills

In a pilot study of drug dose calculation skills, Oldridge and coworkers[11] found that nurses (n = 28) had the lowest scores among different healthcare professionals (n = 111). Low scores were also observed among student nurses,[5,10] which suggest that their calculation skills are a cause for concern. Fortunately, nurses appeared to perform better than did student nurses.[14] In this latter study by Grandell-Niemi and coworkers,[14] the student nurses with the best performance in the drug calculation tests were those who had achieved previous good marks in mathematics or who had studied mathematics more extensively in high school. According to Wright,[15] confident students who enjoy mathematics at school also appear to perform better in drug calculation tests. This pattern was supported by a questionnaire-based study of 137 student nurses, which showed that those who assessed their own mathematical skills as poor found the medication calculation test more stressful than did students who assessed their own mathematical skills as good.[16] Thus, enhancing the general mathematical skills of student nurses seems to be a reasonable way of improving their medication calculation skills. This hypothesis was supported by Adams and Duffield,[17] who showed that repeated mathematical drills improved the ability of student nurses to calculate drug doses.

Anxiety and Self-efficacy

Test anxiety, low mathematical self-efficacy, and low previous mathematical achievement have been shown to have negative effects on the mathematical competence of second-semester baccalaureate nursing students.[13] These findings confirmed an earlier study by Glaister,[12] who found that 20% (n = 19) of student nurses experienced mathematics anxiety and that 14% (n = 13) experienced anxiety during mathematical testing. However, this is not an unambiguous pattern. Walsh[18] found that student nurses (n = 108) generally experienced low mathematics anxiety, and it was related only to testing. The latter study also found that anxiety levels decreased, whereas self-confidence increased, after mathematics tutoring and practice.[18] Therefore, learning strategies that increase the self-confidence and self-efficacy of student nurses but that decrease their anxiety may help to improve their mathematical and medication calculation skills. This is supported partly by previous studies that show that self-efficacy has positive effects on the mathematical performance of both undergraduates[19] and high school students.[20]

Strategies for Teaching Medication Calculation

Various teaching strategies have been developed and tested to address the challenges of poor medication calculation skills among student nurses. Dimensional analysis[6,21] is an "organized approach to setting up mathematical problems,"[6(p315)] which was shown to increase confidence and accuracy during drug dose calculations. The mathematical needs of students were also addressed successfully in a study that used a problem-solving approach based on Landa's Algo-Heuristic Theory of Instruction,[7] which included mathematical examinations during the first, second, third, and fourth semesters, as well as a closely monitored follow-up procedure for students who failed in the first semester. The 4C model[8] is another learning strategy with the following components: compute, convert, conceptualize, and critically evaluate the calculation process and the solutions. The "compute" component involves basic mathematical skills,[8] whereas the "convert" part tests the ability to convert between the metric and apothecary systems, for example, milliliters and milligrams. Two of the four Cs involve basic mathematical skills. Another mathematical problem-solving model is the four-step model of Poyla,[22] which has the following stages: (i) understand the problem, (ii) devise a plan, (iii) execute the plan, and (iv) examine the solution. This model stresses the importance of understanding the mathematical problem before attempting to derive its solutions. In this model, clinical experience and practice are essential for developing an understanding of calculation problems. Indeed, Wright[23] states that "the most important resource for developing drug calculation skills is regular exposure to drug calculation in clinical practice."[23(p878)] This may be the case, but basic mathematical skills are still required before entering clinical practice. This is supported by Wright[9] in a study that explored effective medication calculation teaching strategies, where a three-stage process was found to be most suitable, which comprised (i) addressing mathematical concepts, (ii) teaching medication calculation formulae, and (iii) practicing these skills in a clinical setting.

Electronically supported learning (e-learning) tools and online programs have also been tested, which have produced positive outcomes in terms of medication calculation skills and self-efficacy. McMullan and coworkers[24] used a clustered randomized controlled trial where they compared the use of a computer-based, Internet-independent, interactive e-learning calculation tool with traditional handout support material using second-year nursing students (n = 229). The e-learning tool was found to be more effective, while it was also more user-friendly and provided greater learning enjoyment, which enhanced the students' learning experiences compared with the handouts.[24] Sherriff and coworkers[25] evaluated an online medication calculation education and testing program using RNs and enrolled nurses with a medication endorsement (n = 107), which improved their medication calculation test scores and self-efficacy over time (1-year access).

To sum up, previous studies have shown that student nurses may experience challenges during medication calculations, which are related to their numeracy skills, mathematics anxiety, or low self-efficacy. Studies have also

indicated that several learning strategies may increase the confidence and accuracy of nurses during drug dose calculations, although mathematical drills to improve medication calculation have not been reported widely in the literature. Therefore, it would be useful to investigate alternative or supplementary didactic medication calculation drills, which we discuss in the next section.

THE POTENTIAL ROLE OF DIGITAL GAME-BASED LEARNING IN MEDICATION CALCULATION EDUCATION

In recent decades, game-based learning has been established as a supplement to more traditional didactic methods. This includes a wide variety of games that range from simple paper-and-pencil games to more complex role-playing games. Initially, the experience of DGBL in education of healthcare providers and mathematics will be presented, before describing our experience of the development of a simple DGBL solution, known as "The Medication Game," to elucidate the potential role of DGBL in medication calculation education and medication management.

Games in Education of Healthcare Providers

Recent reviews have shown that many games have been developed, used, and studied in different healthcare provider education areas, including pathophysiology, critical care, clinical judgment, and pharmacology.[26,27] In a systematic review of quantitative studies (empirical and reviews, n = 16) that compared gaming with other didactic methods, Blakely et al[26] failed to determine whether games were better or worse than traditional teaching strategies. Their study reported no evidence that games benefited learning, and they showed that games may only support the learning styles of some students. However, games generally increased the enjoyment of learning and appeared to improve the long-term retention of information. Based on the book *Innovative Teaching Strategies in Nursing*,[28] Blakely et al described seven characteristics of nurses that might be affected positively by gaming. It was suggested that gaming could (1) promote active learning and offer immediate feedback, (2) provide the opportunity to work in a controlled environment, (3) increase the number of experiences available, (4) promote motivational learning, and (5) promote discussions and interactions among students. Furthermore, games may reduce anxiety and stress, break up monotonous lessons, increase motivation, and promote relaxation in the learning environment.[26] A DGBL solution to medication calculation education could exploit these positive effects, which highlights the potential role of DGBL in this area. However, gaming also has disadvantages, including stress and embarrassment related to incorrect answers and the threatening aspects of competition. Some games also require special preparation and instructions, which can be an obstacle to learning. These problems can affect the implementation of DGBL solutions for medication calculation education. However, the flexible design of DGBL solutions to overcome any disadvantages should make it possible to mitigate the effects of these known problems.

Games in Mathematics

Various studies have characterized mathematical games in terms of their effects on increased motivation, enjoyment, and learning. Ke and Grabowski[29] showed that game playing was more effective than drills for promoting the mathematical performance of fifth graders (n = 120), whereas cooperative game playing appeared to be the most effective method for enhancing positive attitudes toward mathematics. Electronic learning environments and computer mathematics drill games also have positive effects on the attitudes of students toward mathematics.[30,31] There appears to be widespread support for the idea that games can improve learning, although this support is not unanimous. In a study of fourth graders using a nationally representative US data set from the National Center for Education Statistics (NAEP 2005) based on more than 3 million respondents, Kim and Chang[32] found that English-speaking students who played mathematical games each day had worse mathematical performance than did those who never played. By contrast, non–English-speaking students who played mathematical games on a daily basis had superior mathematical performance compared with their English-speaking counterparts who never played,[32] which highlighted the ambiguous nature of the learning outcomes of these games. However, some games appeared to have greater educational potential for improving mathematics skills, probably as a supplement to other learning strategies.

Digital Game-Based Learning in Medication Calculation—The Medication Game

A DGBL solution, such as a smartphone application or a computer game, has the potential to improve medication calculation skills directly, by being a tool for drilling the appropriate mathematical topics and, indirectly, by creating a positive environment for learning. Thus, Adams and Duffield[17] showed that gaming based on mathematics drills may improve mathematics skills directly, whereas Blakely and coworkers[26] suggested that games can improve mathematics skills indirectly by reducing anxiety or stress and/or by increasing self-confidence, thereby improving attitudes toward mathematics. Thus, DGBL may have positive effects on the mathematical skills and medication calculation performance of student nurses. However, the challenge is to create a game that can fully exploit the potential of DGBL.

To the best of our knowledge, a DGBL solution that provides medication calculation education to student nurses has not been developed or tested. Thus, we developed The Medication Game at the University of Stavanger in collaboration with the University of Agder, Norway. This game aims (1) to provide simple mathematical and medical calculation drills and (2) to familiarize students and drill them in standard medical units and expressions. The Medication Game is intended to be an intuitive and simple computer-based game for basic training in mathematical concepts without any need for instructions or special preparations, which have been reported to be problematic in some digital learning games.[26] The game has three parts: (1) a training section with three categories, that is, numeracy, where the player trains in basic mathematics, conversion, where the player converts different units, and practical medication calculation; (2) a self-testing section where students receive random tasks from the three categories; and (3) a section with examination questions.

Students familiarize themselves with different types of tasks in the training section, and they have the opportunity to train in specific topics. The players have 60 seconds to answer as many questions as they can, and they are awarded a score. The challenge level of the game is increased by setting a short time limit. According to the professional game designer Raph Koster[33] (former chief creative officer at Sony Online Entertainment), challenge is one of the elements of gaming that creates enjoyment and makes players become competitive, thereby promoting motivational learning. The time pressure also forces players to make intuitive decisions about the correct answers. Students experience stress in normal examination conditions, and the time limitation of The Medication Game may provide added pressure, which aids the preparation for examinations. Stressful situations such as a high workload are also major human factors that cause medical errors.[4] Thus, it is imperative that students are trained to handle stressful situations.

In the self-testing section, immediate feedback is provided in the form of an overall point score after completion. Immediate feedback is known to have a positive effect on students playing educational games.[26] The feedback also makes it easy for students to measure their progress, which might have a positive effect on their motivation and self-confidence. The final section of the game contains examination questions, which were developed to provide students with examples of previous examination questions to help them prepare for a real examination.

Rewards are a fundamental aspect of game playing.[34] In The Medication Game, the basic reward is a point score. The score is represented visually to provide students with an idea of how well they performed. The training tasks use stars, whereas the final score is shown on a graph, which allows students to see how well they performed in each different type of task, that is, numeracy, conversion, and practical medication calculation. The advantage of using a point-based system is that it is easy to compare one's individual progress relative to other students, which provides motivation and enhances learning. The highest scores are saved during the training section, which provides players with an incentive to play again and improve their scores. In the self-testing section, the progress of players is logged on a graph that provides a representation of their progress over time (learning curve).

The element of competition is an important component of game playing, although it can be a double-edged sword. Competition may be a motivating and inclusive factor, but it can also be detrimental to further play. Thus, the scores achieved during the training sections are not displayed or compared with the scores of other players, whereas the results from the self-testing section are logged with the students' nicknames in the ranking of the top 50 high scores. This avoids the negative aspects of gaming, such as potential embarrassment or the threatening nature of some competitive games.[26]

The Medication Game was constructed so that the tasks generated by the game, including the numbers, units, and orders of combinations, are randomized. This ensures that the game can be played repeatedly, which is crucial for a training tool because it avoids making learning monotonous, another advantage of gaming.[26]

Computer anxiety has been observed among student nurses,[12] which diverts the attention of students and presents a dilemma for DGBL. One method for overcoming this problem is to develop an intuitive and simple game without any need for instructions or special preparations. Indeed, ensuring the usability of a computer interface is not an exact science. Our approach to removing significant barriers from a computer-based game was simply a design concept of "less is more." The game is highly structured, and it guides the user through different levels and sections. The interface is graphically clean, and it focuses on the individual tasks of the game separately. All of the tasks are demonstrated, and the operations are limited strictly to the choices of the task at hand, which involves a single mouse click in most cases.

The menus and graphics used by the game have a hand-drawn, pencil-based appearance. We hope this will avoid any possible negative associations with traditional computer programs because it provides a friendlier and less formal appearance both of the computer game and the mathematical and medical calculation training it is designed to facilitate. The usability of the game has not been tested formally. However, the usability of the game was considered regularly throughout the design phase and during the early phase of implementation. We have not received any specific feedback to suggest that the interface is a barrier to the use of the game. By contrast, it is our impression that the barrier to entry is low. Any other observation would of course be contradictory to the purpose of the game and imply the need for a redesign.

The Medication Game and Medication Management

A second section of The Medication Game provides medication management drills in a friendly and safe learning environment with immediate feedback. In this part of the game, players operate in a hospital ward where they are drilled in various areas of medication management, that is, drug calculation, drug preparation, and patient administration. Thus, students can prepare themselves for realistic tasks by using the environment of the computer game to perform the correct procedures, with immediate feedback if needed, before meeting real patients. This part of the game addresses the third approach described above, that is, the practice of mathematical and drug calculation skills in a clinical setting.[9]

CONCLUSIONS

The Medication Game was designed to drill the basic skills of medication calculation (ie, basic mathematics, conversions, and simple drug calculations). The further aims of the game are to improve learning, enhance self-confidence, reduce monotony, and promote active learning, which are all regarded as positive aspects of serious gaming.[26,30,31] In this context, it is interesting that a previous study showed that the most effective medication calculation teaching strategy for student nurses was a three-stage approach, as follows: (1) addressing mathematical concepts, (2) teaching medication calculation formulas, and (3) practicing these skills in a clinical setting.[9] The Medication Game facilitates all of these approaches. However, the effect of The Medication Game on the medication calculation skills of student nurses remains to be tested.

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