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# Development and evaluation of a serious game to support learning among pharmacy and nursing students

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ABSTRACT

Background and purpose: Serious games (SGs) are a digital method that promotes learning through playability. DOSE is a SG that aims to improve the use and navigation of the British National Formulary, a standard medicines reference source. This research aimed to design and examine the playability and perceptions of DOSE within healthcare curricula.

Educational activity and setting: The study used gaming psychology concepts to design DOSE and evaluated it across two cohorts of students from the undergraduate pharmacy and nursing courses at Kingston University. Pre- and post-game questionnaires were utilised to examine usability and student perceptions. SG playability and validity were measured against standard criteria using validated assessment frameworks. Cronbach's α was calculated to determine the internal reliability of the framework assessments.

Findings: The SG was validated for playability, functionality, and rationale ($\alpha \geq 0.8$). The majority (95%, $n = 95$) of pharmacy students reported they would use DOSE again with 58% ($n = 58$) indicating they would use the SG as a revision tool. DOSE was also perceived positively among the nursing cohort, with 84% ($n = 118$) indicating they would like to see DOSE embedded within the curriculum; 77% ($n = 108$) agreed DOSE had helped to improve their knowledge of pharmacology.

Summary: DOSE playability and validity was reported by pharmacy students. Nursing students reported a significant increase in confidence using the BNF and overall high acceptability of DOSE as a SG. DOSE was found to be a usable SG model across both cohorts.



## Background and purpose

Serious games (SGs) are an emerging concept in education that focuses on the adaptation of teaching methods to provide a digital platform for student development and learning. Unlike traditional games that almost exclusively provide entertainment, SGs centre on user development and behaviour change, with examples of adoption across industries such as healthcare and business.[1,2] SGs rationalise incorporation of both elements of "play" and "learning" with a view to actively engage the user. Engagement in learning exercises

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(often referred to as "active learning") has been demonstrated to improve knowledge retention.[3,4] Promotion of active learning can also be mediated through student motivation, particularly with teaching methods that tackle the numerous learning styles of the evolving student population.[5] Therefore, SGs offer a unique approach to potentially address the learning needs of students in an era of technological development, particularly in healthcare education.

When exploring the demand of SGs in postgraduate medical education, Graafland et al[6] defined SGs as "virtual learning environments designed to activate, entertain and educate the player," thus they need to combine elements of student engagement and motivation within a digital platform. This may be pertinent for healthcare professionals given that poor decision making from a lack of experience or knowledge can lead to potentially harmful outcomes for patients. A 2011 systematic review in of technology-enabled simulation for healthcare education demonstrated positive outcomes for students' knowledge, skills and behaviours, that directly translated to moderately positive effects on patient-related outcomes.[7] Technologies such as SGs provide a safe learning platform in which students can make mistakes without the equivalent real-life risk. Connolly et al[8] and Dominguez et al[9] suggest that developing these clinical skills and knowledge in a non-threatening environment may support self-regulated and productive learning outside of more conventional learning spaces such as the lecture hall.

Interest and implementation of SGs within healthcare education has recently been explored as an alternative strategy to traditional didactic classroom teaching.[10,11] A 2015 cross-sectional study by Chang et al[10] found that 90.5% ($n$ = 450/490) of undergraduate pharmacy students were interested in playing SGs as part of their curriculum. Work by Kron et al[12] also describes the enthusiasm of medical students for an authentic simulation within their curriculum. A vast majority of students agreed that they were happy with the idea of technology integration as part of the curriculum (98%, 195/200) and felt more technologies could be used to enhance their education (96%, 198/208). Personal development played an important role in perceived self-regulated learning with 77% ($n$ = 154/200) agreeing they would use SGs in order to achieve a goal outside of their teaching hours. The emerging evidence emphasises student desire for the integration of technology with SGs being perceived as an engaging and motivating model for productive learning outside of the classroom.[8,9] These findings also closely reflect the general preferences of students reported in the literature for further incorporation of digital technologies as part of their formal education, even beyond healthcare curricula.[10–12] Despite this, more evidence is needed to specifically evaluate the role and perceptions of SG integration within healthcare education.

### *Developing a serious game: from Pharmacy Challenge to DOSE*

Following a brief needs assessment, a SG known as Pharmacy Challenge was designed to provide support for undergraduate pharmacy students.[13] Pharmacy Challenge sought to improve students' abilities to navigate the British National Formulary (BNF), a reference source used by United Kingdom healthcare professionals for information on prescribing, supply, and monitoring of medicines. The BNF is also used as the primary resource for information in pharmacy undergraduate students' case-based learning activities and assessments such as objective structured clinical examinations (OSCEs). A cross-sectional study of students was performed to review the design, content, and motivation to use the SG, before under-going an iterative design process based on student feedback.[13] Upon completion of the study, the final iteration, known as DOSE, was developed as a novel online e-learning platform for undergraduate pharmacy students (Appendix 1).

The previous iteration of DOSE, when known as Pharmacy Challenge, was shown to increase students' confidence and use of the BNF.[13] Building on previous work, this study aimed to optimise the SG model with a focus on improvements in design and playability whilst validating the model against accepted SG criteria. Moreover, by extending the use of DOSE beyond pharmacy students, this study sought to demonstrate the usability of a SG model within the wider context of healthcare curricula.

### *Educational activity and setting*

This study used a mixed-methods approach to develop and evaluate DOSE across three distinct phases. Phase A focused on the design rationale for DOSE, specifically highlighting the types of users and the relevant strategies needed to engage these users. Phase B implemented validated tools to assess both the playability and perceptions of DOSE as a SG. Finally, the usability of DOSE beyond the pharmacy curriculum was explored in Phase C of the study. Ethical approval was received from the Faculty Research Ethics Committee (1213/045).

#### *Phase A: DOSE design rationale*

To develop DOSE as an optimised SG model for evaluation in this validation study, additional design features were implemented following previous feedback from students.[13] The concepts of game psychology, particularly work by Bartle,[14] were considered in the revisions made to DOSE, which included identification of the different types of players and their needs as well as specific gamification methods to drive user engagement. Four main player types are defined by Bartle,[14] including the Achiever, Explorer, Socializer, and Killer. The Achiever can be summarised as a player who focuses on demonstrating skill and an elite status. Discovery and curiosity are the main drivers for the Explorer, whereas building networks, friends, and contacts are key priorities for the Socializer. The Killer prefers to beat direct competitors through winning and ranking.

Targeted design features were integrated during the optimisation process to promote playability. As with previous SG versions, points were accumulated based on correct answers. To engage Killer and Achiever players, point accumulation could be translated into achievements/medals, titles, and ranks in game as well as impacting a public leader board with scores on the homepage. The leader board was part of a wider social system aimed at the Socializer. Furthermore, a "players online" function was developed to provide information on current active users of the SG with the intent of creating a sense of a social network for players during their gaming

experience. Explorer players were targeted specifically using a narrative that was both interesting and relatable, with evolving questions based on the university itself. The scenario characterised players as an archetypal hero, answering challenging questions correctly to save university students from a virus that had spread around campus. Furthermore, interaction with DOSE offered players the opportunity to engage with less widely covered areas of clinical content within the BNF. Inquisitive students could therefore expand their clinical knowledge through gamification of discovering new BNF content with the incentive to unlock clues and hints to answer more difficult questions throughout DOSE.

The concepts of Bartle[14] have been integrated throughout the design of DOSE in addition to more generic features for enhancing playability. These included an instant feedback mechanism after each question, a clear game introduction with goals and rules, and a minimalist approach to the SG aesthetics that incorporated animations related to pharmacy (e.g., pills, bacteria). DOSE was designed as a "progressive web app," available via both computer browser and mobile phone, with the intention of enhancing both accessibility and functionality.

*Phase B: Exploring playability, perceptions, and validation*

*Sample population.* Students in their second, third, and fourth year of the pharmacy course, otherwise referred to as Levels 5, 6 and 7, were identified as the most appropriate study participants. These student cohorts were expected to benefit the most from additional exposure to clinical learning while using DOSE given that their upcoming clinical exams were planned to take place shortly after the research project. Overseas Pharmacists Assessment Programme (OSPAP) students who were studying for a pharmacy practice diploma were also included in the study. First year students (Level 4) were excluded based on the consideration that they had very little experience with the BNF and clinical content from the course, and therefore would not necessarily benefit from the study. Moreover, based on the theory of flow by Nakamura and Csikszentmihalyi,[15] among an inexperienced cohort there exists a greater likelihood of self-consciousness and a lack of confidence that may have prevented students from reliably engaging in the challenges set out by DOSE. Hence, the authors choose to exclude this cohort to avoid potential distortion of the study results. Using Raosoft (Raosoft, Inc.), a minimum sample of 187 participants was calculated to achieve a 95% confidence interval with a 5% margin of error based on a total sample of 360 students.

*Questionnaire design.* An online questionnaire (Appendix 2) was designed in order to assess playability, students' perceptions of DOSE, and validity based on recognised criteria for successful SG design. Five demographic items and two statements investigating previous use of computer games and perceptions of educational games were included.

*Playability.* Within the questionnaire, a validated 16-item model known as the Play Experience Scale (PES-16)[16] was used to evaluate the playability of DOSE. PES-16 explores five key components of play behaviour derived from the literature (Table 1). The 16-item tool is comprised of 5-point, Likert-scale questions ranging from strongly disagree (1) to strongly agree (5). Weighted averages were calculated for all Likert-scale questions used within the study.

*Validation.* An adapted Assessment Framework (aAF-14) derived from the five main themes of SG assessment as defined by Graafland et al[17] was devised in order to systematically assess DOSE within the context of an SG in healthcare education. The original Assessment Framework (AF)[17] contains 62 items, not all of which were deemed relevant for the study. At this stage, the study was localised within the pharmacy department, therefore questions under the domains of Data Protection and Game Description, which include questions on commercial access, advertising, and nonanonymised data were outside the scope of the project. The Validity domain was in part approached through this study in user testing with a different cohort of users, of which we invited student nurses. However, the authors felt that Validity could not truly be assessed until a study could be constructed whereby DOSE was compared in a controlled fashion against other methods of teaching as part of a longitudinal assessment of outcomes and/or skills. Hence, the two remaining concepts examined by the AF, Rationale and Functionality, were adapted for use in this study. These two major concepts relevant to DOSE were explored to assess the seriousness of the SG using the adapted 14-item scale, which consisted of 5-point Likert-scale questions ranging from strongly disagree (1) to strongly agree (5).

*Perceptions of DOSE.* Ten questions focused on student perceptions of DOSE were designed to capture feedback on elements of the SG, including the medals system, preference on privacy of results, preferred device to play on, and the perceived educational benefit in terms of knowledge retention or performance in examinations. Ten "best-worst" questions were designed to assess eight DOSE design features. Only four features were included for each question, with each feature appearing in five out of 10 questions. Therefore, the

**Table 1**
Description of PES-16.

| Concept | Description ofcConcept |
|---|---|
| Autotelic experience | Intrinsic motivation of the player to engage in the play experience |
| Freedom | The ability to perform actions that the player wishes to perform during the play experience |
| Focus | Immersion within the play experience reflected by loss of concern or intense concentration |
| Absence of extrinsic motivation | The lack of impact from external pressures on the play experience |
| Direct play assessment | Degree of engagement in the play experience |

PES-16 = 16-Item Play Experience Scale.

total maximum score for a feature was 40 (i.e. students could select one feature five times as their favourite feature, scoring 8 points per selection).

*Pilot study*. Level 7 students ($N = 12$) took part in a pilot study to examine face and content validity of the questionnaire prior to dissemination. These students were excluded from the main study. Following the pilot, two questions related to the DOSE ranking system were amended to enhance clarity.

*Questionnaire distribution*. The questionnaire was made available online via SurveyMonkey (SurveyMonkey) between February and March 2017 to students in Level 5, 6, 7, and OSPAPs. Students could access the questionnaire via the online university portal Blackboard (Blackboard, Inc.), where they would be required to provide their unique student identification number to prevent questionnaire duplication. The study collected 100 online responses from students across all four identified student cohorts. Data were exported to Excel, version 16 (Microsoft Corp.) for interpretation using descriptive statistics. Additional data analysis was completed using SPSS, version 19 (IBM Corp.).

*Internal consistency*. Questionnaire responses for PES-16 and the aAF-14 were evaluated using Cronbach's α to assess the internal consistency of items examined. Internal consistency reflects the reliability of a tool in measuring its intended outcome. For this study, we assessed how reliably PES-16 could measure the playability of DOSE as well as how reliably aAF-14 could measure two of the key criteria for successful SG design as a method of validation. A value of >0.7 was deemed as an acceptable level of internal consistency.[18]

*Phase C: Usability beyond the pharmacy curriculum*.

*Sample population*. To assess the usability of DOSE within the wider context of healthcare education, a cross-curricular study of Level 5 nursing students using the SG, followed by a post-game questionnaire, was undertaken in February 2017. To achieve this, the Level 5 nursing syllabus was reviewed in order to identify clinical topics most prominently taught as part of the course. Examples of topics included multiple sclerosis, heart failure, pain management, wound management, obesity, diabetes, and chronic obstructive pulmonary disease. From the current bank of DOSE questions, 50 questions relevant to the nursing syllabus topics were selected (Appendix 3) for the usability study. A session that all Level 5 students were due to attend ($N = 140$) was targeted for introducing DOSE, followed by questionnaire distribution. Using Raosoft (Raosoft Inc.), a minimum sample of 103 participants was calculated to achieve a 95% confidence interval with a 5% margin of error.

*Questionnaire design*. The questionnaire consisted of 13 items (Appendix 4) that explored students' views of DOSE in terms of usability and acceptability using a mixture of yes/no, 5-point Likert scale, preference, and open-ended style questions as well as a small section for demographics. Students were asked to rate their confidence in using the BNF both before and after exposure to DOSE for comparison. The motivation to play and perceptions of DOSE, including design features, were also examined as part of the usability study.

*Pilot study*. Following development of the amended version of DOSE and postgame questionnaire, Level 5 nursing students ($N = 6$) participated in a brief study pilot for face and content validity. Responses to both DOSE and questionnaire completion were positive with no resulting changes required to either study tool.

*Questionnaire distribution*. Nursing students completed one round of six questions, with two and a half min to complete each question. DOSE rounds usually consist of 10 questions with a two-min time-limit per item, however these amendments were made due to nursing students having less experience with the BNF compared to pharmacy students. During the session, all attendees ($N = 140$) utilised the modified DOSE model as well as completed the post-game questionnaire. Data from the questionnaire were transcribed to Excel, version 16 (Microsoft Corp.) for interpretation using descriptive statistics. Additional data analysis was completed using SPSS, version 19 (IBM, Corp.). Likert scale weight averages were examined for significance using two-tailed unpaired *t*-tests. Significance was set at $P \leq .05$.

## Findings

*Phase B: Exploring playability and validation*

*Demographics*. The study captured 100 participants predominantly between 19 and 26 years of age (92%, $n = 92$). Male and female participants accounted for 37% and 63%, respectively. Almost half of the participants (47%) were from Level 6. Levels 5 and 7 accounted for 27% and 24% of the sample, respectively, with the smallest participating cohort being OSPAP students (2%). However, this finding was expected given that the total number of OSPAP students was 10 for the academic year 2017. Less than half (45%) of respondents reported that they do not play games. The remaining participants reported varying levels of game use, with the modal response being that games were used by students a few times a week (14%). Demographic characteristics are presented in Table 2.

*Internal consistency*. Cronbach's α was calculated to determine the internal consistency of both the PES-16 and aAF-14 scores. Both measures showed significant internal consistency based on acceptable values for Cronbach's α being >0.7 (PES-16 = 0.809 and aAF-14 = 0.857).

**Table 2**
Demographic characteristics of respondents (Phase B) ($N$ = 100).

| Characteristic | n (%) |
|---|---|
| Age | |
| 19–22 years old | 65 (65) |
| 23–26 years old | 27 (27) |
| 27–30 years old | 4 (4) |
| >30 years old | 4 (4) |
| Gender | |
| Male | 37 (37) |
| Female | 63 (63) |
| Year of Study | |
| Level 5 (Year 2) | 27 (27) |
| Level 6 (Year 3) | 47 (47) |
| Level 7 (Year 4) | 24 (24) |
| OSPAP | 2 (2) |
| Frequency of Playing Games | |
| I don't play games | 45 (45) |
| Once a month | 13 (13) |
| Once every 2 weeks | 7 (7) |
| Once a week | 12 (12) |
| Few times per week | 14 (14) |
| Everyday | 9 (9) |

OSPAP = Overseas Pharmacists Assessment Programme.

*Playability*. One of the primary aims of this study was to determine the playability of DOSE using a validated tool, PES-16. Three of the PES-16 items were negative statements, and hence were reverse coded. Weighted averages were calculated for each statement (Table 3). Of the 13 forward coded items, all statements scored ≥3.5 as a weighted average, suggesting that more often than not students agreed with the statements, thus expressing that DOSE had provided evidence of playability across the major elements of PES-16. Responses to the three reverse coded items were ambivalent, reflecting that overall students had mixed positive and negative perceptions of DOSE based on these specific components.

*Validation*. The aAF-14 was devised to systematically assess recognised criteria of successful SG design within the context of healthcare education. Six items related to the concept of SG Rationale and eight items for the concept of Functionality (one of which was reverse coded) were assessed as part of aAF-14 tool. Weighted averages were calculated for each item (Table 4). All six items relating to Rationale received weighted averages of >3.5, hence students recognised this concept as part of the design for DOSE. With respect to Functionality, two items scored <3.5, "The potential drawbacks of DOSE are disclosed to me" (3.05) and "I believe the DOSE game has potential undesirable effects on my learning" (2.52). This indicates that students, more often than not, did not believe the game has drawbacks.

**Table 3**
PES-16 Results (Phase B) (N = 100).

| Playability | Weighted average |
|---|---|
| If I wanted to do something in the game, I was able to do it | 4.21 |
| I was able to make the game do what I wanted it to | 4.19 |
| The game gave me the freedom to act how I wanted to | 4.09 |
| I was not worried about someone judging how I performed in the game | 3.66 |
| Regardless of how I performed in the game, I knew there wouldn't be a real-world consequence | 3.97 |
| My performance in the game was not going to matter outside of the game | 3.57 |
| When I was using the game, it felt like I was playing rather than working | 3.49 |
| I would characterize my experience with the game as playing | 3.86 |
| I felt like I was playing a game rather than working | 3.73 |
| When I was using the game, I was focused on the task at hand | 4.18 |
| I wanted to do well in the game, "just because" | 3.67 |
| When I was using the game, I wanted to do as well as possible | 4.40 |
| I tried to succeed in the game because I felt like it | 4.14 |
| The game made it difficult to perform the actions that I wanted to[a] | 2.46 |
| I felt like I had to do well, or the experimenter would judge me[a] | 2.65 |
| Using the game felt like work[a] | 2.53 |
| Cronbach's α | 0.809 |

PES-16 = 16-item Play Experience Scale.
[a] Item was reverse coded.

**Table 4**
Adapted AF-14 results (Phase B) ($N = 100$).

| Validation element | Weighted average |
|---|---|
| Rationale | |
| I understand the purpose of DOSE | 4.43 |
| The purpose of DOSE was disclosed to me | 4.11 |
| I believe DOSE is aimed at those in the pharmacy profession | 4.36 |
| I believe DOSE caters to a specific stage of pharmacy education/training | 4.05 |
| The intended user group of DOSE was disclosed to me | 3.85 |
| I believe DOSE is used for pharmacy training or educational purposes | 4.43 |
| Functionality | |
| Playing DOSE game has enhanced my pharmacy knowledge | 4.26 |
| Playing DOSE game has enhanced my ability to use the BNF | 4.28 |
| DOSE was appropriate for the intended learning objectives | 4.25 |
| The ranking system is clear to me | 4.01 |
| The medals system is clear to me | 3.95 |
| The points system is clear to me (points per question) | 4.13 |
| The potential drawbacks of DOSE were disclosed to me | 3.05 |
| I believe the DOSE game has potential undesirable effects on my learning[a] | 2.52 |
| Cronbach's α | 0.857 |

AF-14 = 14-item Adapted Assessment Framework; BNF = British National Formulary.
[a] Item was reverse coded.

*Phase B: perceptions of educational games and DOSE*

With respect to attitudes towards educational games, the most common response from participants was that they perceived them to be useful (45%). This finding was followed by 37% reporting that they felt educational games were great. Thoughts that they were boring (3%) or didn't work (2%) were reported, however these findings were from a minority of the sample. Six items exploring perceptions of DOSE were included as part of the questionnaire. Weighted averages were calculated for each item, with each item scoring >3.5, suggesting a strong agreement with the statements. Students reported that they felt DOSE had educational benefit (weighted average 4.48) and would be useful in revision for curricular assessment such as OSCEs (4.46). Student responses on the entertainment value of the DOSE storyline were agreeable (3.57). Students' perceptions of educational games and DOSE are reported in Table 5.

The most common response for motivation to use DOSE was that the game was educational (35%). Other factors, including good game performance, DOSE being reflective of future assessments, and the accessibility as a learning tool, were cited by students during the study (37%). Encouragingly, 95% ($n = 95$) of participants agreed they would play DOSE again in the future. Reasons for this included use as a revision tool (58%) and because the game was fun (30%). In relation to the improvement of DOSE, 61% reported that DOSE required no improvements, while 7% suggested questions could be split into themes or topics. Only 4% ($n = 4$) suggested that the correct answer to questions should be provided at the end of the game.

DOSE utilised a public leader board mechanic, whereby students could see the ranking of other students on the DOSE main screen interface (Appendix 1). Overall, 47% wanted to keep the public scoring, with 53% supporting privatisation of their scores. Additionally, ranks and medals could be won through the accumulation of points during game attempts. Students were asked to preference these rankings. Of the 15 ranks, those most appealing to participants included Pharmacist, Drug Consultant, and Graduate. These titles may have been the most preferred given that they resonate with potential future titles for students upon completion of their degree. Ranks that identified participants as DOSE novices were the least preferred, including Newbie and Student, which may reflect that students do not wish to be considered inexperienced. When given the option to suggest alternative rankings, students opted for titles that again would reflect potential roles in future practice, including Industrial Pharmacist, Junior Pharmacist, and Pre-registration Pharmacist.

Preferences for DOSE features were analysed using frequency of occurrence in a best-worst question format to elicit consistent scoring of features. Participants were asked a series of 10 questions, five for the most preferred and five for the least preferred feature. Each serial question presented a combination of four out of the eight total features, which were then ranked by participants from worst to best. Cumulative scores for features across the question series were then translated into respective means, where a score of "5" represented "most preferred/least preferred" depending on the question series. The results of the features analysis are presented in Table 6. Feedback at the end of each round and hints were deemed to be two of the most preferred features, whereas the storyline and ranking system were viewed as two of the least preferred features. Interestingly, the time limit scored in the top three of both categories, demonstrating it to be perceived as both a strong and weak feature of the SG depending on the user.

*Phase C: usability beyond the pharmacy curriculum*

*Demographics*. Participants from the Level 5 nursing cohort ($N = 140$) had ages that ranged from 18 years to ≥37 years, with almost half of the students (47%) being in the age range 18 to 24. A significant number of participants that attended were female (84%) with

**Table 5**
Perceptions of educational games and DOSE (Phase B) (N = 100).

| Perception | Result |
|---|---|
| Attitude towards educational games | n (%) |
| They are boring | 3 (3) |
| They don't work | 2 (2) |
| Not sure | 13 (13) |
| They seem useful | 45 (45) |
| They are great | 37 (37) |
| Motivations for playing DOSE | n (%) |
| It is educational | 35 (35) |
| DOSE contains hints | 9 (9) |
| DOSE could be developed into an app | 3 (3) |
| DOSE contains prizes | 3 (3) |
| Different game modes | 10 (10) |
| Competition | 3 (3) |
| Other factors[a] | 37 (37) |
| Improvement suggestions for DOSE | n (%) |
| DOSE needs no further improvements | 61 (61) |
| Separate questions in themes/topics | 7 (7) |
| Provide the correct answer to questions | 4 (4) |
| Add sound effects | 6 (6) |
| Reduce the number of ranks | 4 (4) |
| Develop into an app | 3 (3) |
| No comment | 15 (15) |
| Future use of DOSE | n (%) |
| Would play again in the future | 95 (95) |
| I would play for the purpose of revision | 58 (58) |
| I would play for the purpose of fun | 30 (30) |
| No comment | 12 (12) |
| Perceptions of DOSE | Weighted average |
| The game has educational benefit | 4.48 |
| The game has improved your knowledge | 4.32 |
| The game will be useful during OSCE/APC revision | 4.46 |
| The questions are relevant to the Pharmacy Curriculum | 4.43 |
| The hints were helpful | 3.98 |
| The storyline of the game was entertaining (a virus infecting campus) | 3.57 |

APC = Assessment of Professional Competence; OSCE = objective structured clinical examination.
[a] Other factors included good game performance, DOSE reflecting future assessments, and accessibility as a learning tool.

only a small minority of male students (11%). However, this result was expected given that nursing cohorts within higher education are predominantly female. Only 2 students (1.4%) reported never having played an educational game, with most describing educational games as either very useful (45%) or beneficial (50%). Demographic characteristics as well as experience with educational games are presented in Table 7.

**Table 6**
Best-worst DOSE feature responses (N = 100).

| Most preferred[a] | Mean score |
|---|---|
| Time limit | 3.07 |
| Feedback at the end of the round | 2.64 |
| Hints | 2.51 |
| Medals | 1.92 |
| Storyline | 2.40 |
| Layout | 1.87 |
| Leaderboard | 2.03 |
| Ranks | 1.89 |
| Least preferred[b] | Mean score |
| Time limit | 2.92 |
| Feedback at the end of the round | 2.36 |
| Hints | 1.83 |
| Medals | 2.07 |
| Storyline | 3.15 |
| Layout | 1.78 |
| Leaderboard | 2.45 |
| Ranks | 2.87 |

[a] Answers were rated on a scale where 1 = least preferred and 5 = most preferred; time limit, feedback, and hints were the three most preferred features.
[b] Answers were rated on a scale where 1 = most preferred and 5 = least preferred; storyline, time limit, and ranks were the three least preferred features.

**Table 7**
Demographic characteristics of respondents (Phase C) (N = 140).

| Characteristic | n (%) |
|---|---|
| Age | |
| 18–24 years old | 66 (47) |
| 25–30 years old | 27 (19) |
| 31–36 years old | 16 (11) |
| ≥37 years old | 20 (14) |
| I'd rather not say | 11 (8) |
| Gender | |
| Male | 15 (11) |
| Female | 118 (84) |
| Prefer not to say | 7 (5) |
| Ethnicity | |
| White | 53 (38) |
| Asian/Asian British | 21 (15) |
| Black/African/Caribbean/Black British | 46 (33) |
| Mixed/Multiple Ethnic Group | 21 (15) |
| Prefer not to say | 10 (7) |
| Other | 0 (0) |
| Experience of educational games | |
| I have never played one | 2 (1.4) |
| They are not useful | 3 (2.1) |
| They are boring | 0 (0) |
| I'm not sure | 2 (1.4) |
| They seem beneficial | 70 (50) |
| They are very useful | 63 (45) |

*Confidence and usability*. An increase in perceived usefulness was observed after using the SG (3.72 vs. 4.24), however this was not found to be statistically significant ($P > .05$). Across the four statements related to changes in confidence before and after using DOSE, the greatest increase was seen in speed at navigating the BNF (2.06 vs. 2.88), followed by knowledge of different sections (2.17 vs. 2.95), ability to extract information (2.46 vs. 3.09) and knowing where to look for answers (2.44 vs. 3.06). The change in confidence was found to be statistically significant ($P < .001$). Individual statement responses and significance values are shown in Fig. 1 and Table 8.

*Phase C: perceptions*

DOSE was viewed positively, with 81% ($n = 114$) reporting they agreed or strongly agreed that the SG was both enjoyable and that they felt they were learning whilst playing. Learning in an environment without real-life consequences was assessed. More than two-

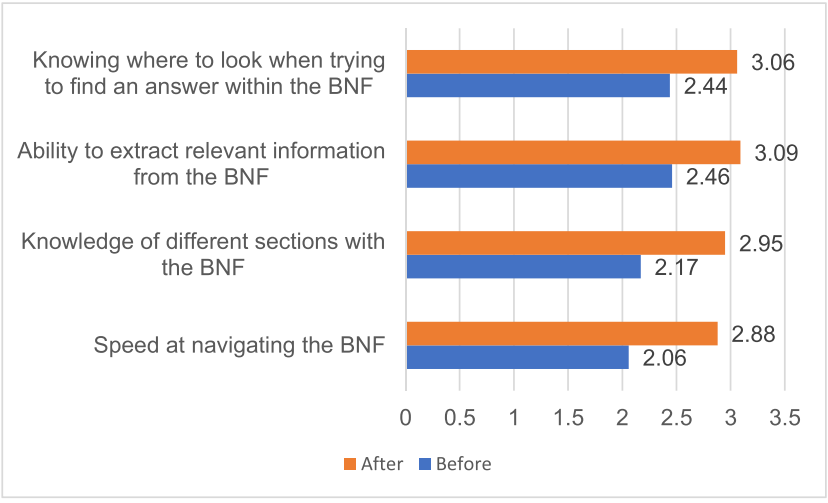


**Fig. 1.** Confidence comparison before and after playing DOSE (N = 140). BNF = British National Formulary.

**Table 8**
Confidence comparison before and after playing DOSE ($N = 140$).

| Confidence domain | Mean score before game | Mean score after game | *P* value |
|---|---|---|---|
| Speed at navigating the BNF | 2.06 | 2.88 | <0.001 |
| Knowledge of the different sections within the BNF | 2.17 | 2.95 | <0.001 |
| Ability to extract relevant information from the BNF | 2.46 | 3.09 | <0.001 |
| Confidence in knowing where to find an answer within the BNF | 2.44 | 3.06 | <0.001 |

BNF = British National Formulary.

thirds (69%) either agreed or strongly agreed that they felt comfortable learning in this way without concerns around their performance. Over half the respondents (56%) agreed or strongly agreed they could easily navigate around DOSE (Table 9).

The study cohort strongly agreed that they would like to see DOSE embedded within the nursing curriculum (84%), that they would recommend DOSE to other nursing students (89%), and would like to use DOSE again (89%); this demonstrated high acceptability of the SG (Table 9). With respect to nursing curricula, 83% of students agreed or strongly agreed that DOSE questions were relevant to their syllabus and 77% agreed or strongly agreed that DOSE had helped to improve their knowledge of pharmacology (Table 9).

When considering design features of DOSE, the most liked feature was found to be the layout of DOSE (33%), whereas the question countdown timer was reported as the least favourite feature (61%) (Figs. 2 and 3). Similar to the pharmacy cohort, feedback was perceived very positively and was the second favourite feature of DOSE among nursing students (19%).

## Discussion

### *Understanding the needs of students*

Despite on-going debate regarding the legitimacy of the term digital native, it is evident that students desire integration of digital technologies as part of their education.[10,12,19] Margaryan et al[19] describe that students are not deviating from traditional pedagogical strategies but desire implementation of digital media within their educational framework. This finding supports our understanding of student diversity in terms of learning needs and recognises that novel digital pedagogies alone cannot provide for all students.[20] Work by Balakrishnan and Gan[21] has provided further evidence for the multiplicity of learning styles, with significant variation in the use of technology as a learning tool, dependent on the type of student learner.

It is clear that a one size fits all approach will not suffice. Instead, development of digital methods in teaching should focus on supplementation of the current learning framework. However, designing these methods to be both motivating and engaging whilst providing educational benefit can be particularly challenging. SGs are no exception. Bogost[22] highlights that for games to be good, they are often complex; however, this makes them hard to create. Therefore, the approach to SG design and implementation should be systematic, with a focus on user-development such as in Phase A of the study.

### *Playability, perceptions, and validation.*

SGs are vulnerable to design deficiencies that hinder their acceptability and utility as effective learning tools within medical education. Use of a validated approach to design DOSE was an essential component of the study to avoid common pitfalls associated with SG implementation such as lack of content expertise or designs that do not support learning.[23] The AF was designed as a means of systematic SG assessment to overcome such barriers to SG development. Therefore, the aAF-14 provided a foundation for DOSE validation based on two criteria, Rationale and Functionality, that were explored in this study. Results from the questionnaire identified positive skews towards student recognition of Rationale and Functionality with overall weighted averages calculated as 4.21 and 3.80, respectively. The AF components not evaluated in the study, Game Description, Validity, and Data Protection, were not applicable based on

**Table 9**
Overall perceptions of DOSE (N = 140).

| Perception | Strongly disagree, n | Disagree, n | Neutral, n | Agree, n | Strongly agree, n | Mean |
|---|---|---|---|---|---|---|
| I enjoyed playing DOSE | 3[b] | 5 | 18 | 92 | 22 | 3.9 |
| I could easily navigate around DOSE | 6 | 18 | 37 | 58 | 21 | 3.5 |
| I felt more comfortable learning through DOSE as I knew regardless of my performance there wouldn't be any real-life consequences | 3 | 10 | 30 | 65 | 32 | 3.8 |
| I was learning whilst playing DOSE | 1 | 6 | 19 | 78 | 36 | 4.0 |
| I would like to see DOSE embedded in the syllabus | 3 | 4 | 15 | 76 | 42 | 4.1 |
| I would recommend DOSE to other nursing students | 2 | 2 | 12 | 80 | 44 | 4.2 |
| I would like to use DOSE again | 3 | 4 | 8 | 83 | 42 | 4.1 |
| Questions were relevant to the syllabus | 1 | 6 | 17 | 93 | 23 | 3.9 |
| DOSE helped improve my knowledge of pharmacology | 1 | 4 | 27 | 78 | 30 | 3.9 |

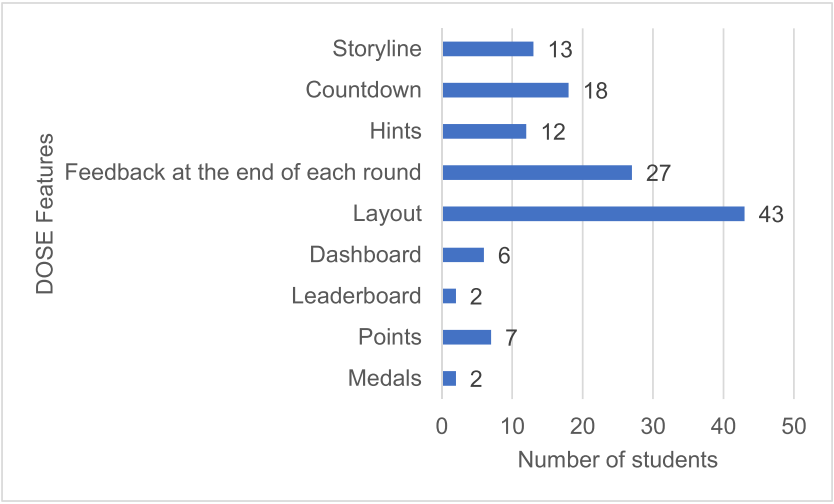


**Fig. 2.** Favourite feature of DOSE (Phase C) (N = 140).

this current stage of SG design and were therefore excluded from the study. However, further design optimisation will include all elements for full validation.

Another intrinsic component of successful SG design is playability. The study incorporated PES-16 as a validated model for determining the playability of DOSE as an SG within pharmacy education. Pavlas et al[16] define play behaviours as intrinsically motivated (Autotelic Motivation) and freely performed (Freedom) by the player. Encouragingly, this perceived behaviour was reflected in pharmacy student responses to DOSE, with all three PES-16 statements exploring SG Freedom scoring weighted averages >4.0 as well as two statements related to Autotelic Motivation scoring >4.1. Improvements in player engagement have been observed with increasing levels of freedom within gameplay mechanics.[24] The degree of game freedom can therefore play a significant role in active learning, and potentially knowledge retention as a component of overall playability.[8,9] The concept of playability was well accepted across the participant sample evaluated using PES-16.

Further evidence to support the playability of DOSE was provided using the Cronbach's α analysis. A value of 0.809 demonstrated that the five components of playability, as defined by Pavlas et al.,[16] were measured reliably throughout. Having validated the playability of DOSE, nursing students' perceptions regarding playability were further sought. The nursing cohort, with the majority agreeing or strongly agreeing, found that DOSE was enjoyable and felt they were learning whilst playing. Previous work has emphasised that

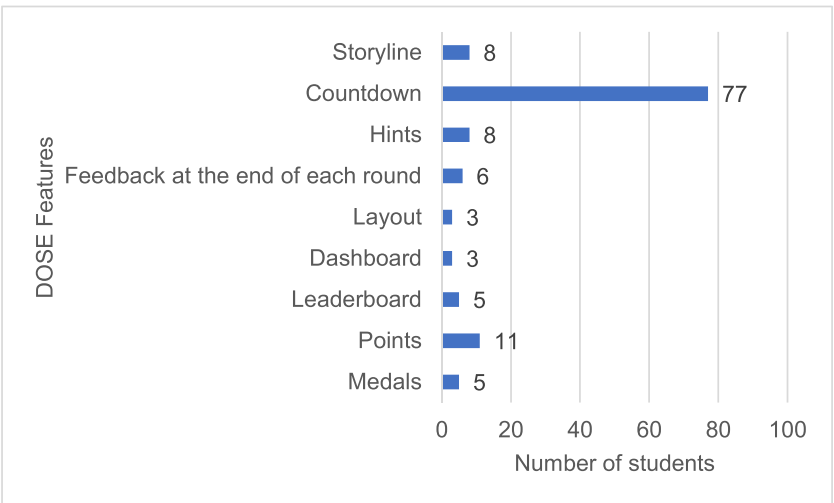


**Fig. 3.** Least favourite features of DOSE (Phase C) (N = 140).

playability may also be an important determinant in educational outcomes, demonstrating improved performance in undergraduate assessment after curricular implementation of educational games when compared to standard didactic methods alone.[25]

*Confidence and usability*

Outcomes and curricula play an essential part in both SG development and implementation. This concept is emphasised by Gunter et al[26] who describes how relevant SG content that overlaps with educational curricula helps to support overall player engagement. When pharmacy students were asked about the relevancy of DOSE to their curriculum, they agreed that the questions were relevant (weighted average 4.43). Furthermore, students agreed that DOSE had an educational benefit (4.48), had improved their knowledge (4.32), and would be a useful revision tool for curricular assessments such as OSCEs (4.46). From the perspective of the nursing cohort, 83% felt the questions were relevant to the syllabus, with 84% strongly agreeing that DOSE should be embedded within their curriculum. Students felt motivated by both the content and perceived outcomes of using DOSE. Furthermore, a more immediate significant outcome to improvements in confidence was observed among nursing students when navigating the BNF. These findings are consistent with Kron et al.,[12] who found students perceived SGs as a potential learning tool even beyond the classroom setting. Such elements of SG design such as content relevancy and perceived educational value support the authenticity of the learning experience, which may serve student motivation and engagement with SGs as a pedagogical method.[10,12]

Feedback may be another contributing component to perceived changes in confidence and knowledge among students. Both cohorts for this study rated feedback as one of the most preferred features of DOSE. Students receiving poor feedback may often feel despondent and less likely to engage with suggested changes that may positively impact their learning.[27] In contrast, effective feedback has been demonstrated to improve clinical skills, confidence, and curricular outcomes for both pharmacy and nursing students when delivered through non-didactic methods.[28,29] Although more work is needed to evaluate the impact of feedback from DOSE on outcomes such as assessments and clinical skills, this study has provided additional evidence to support the role of SGs as a learning modality within clinical curricula.

*Limitations*

Limitations for this study included the sample size for Phase B and the lack of validation models integrated in Phase C. However, the latter was deemed unnecessary as this would lengthen the survey for participants in the nursing cohort, considering the game was already validated. The authors note that the results of Phase B should be treated cautiously given that a minimum sample of 187 was not achieved.

*Recommendations*

When considering implementation of SGs within a clinical curriculum, it is important to utilise an iterative design process which includes students as part of the SG development. Seeking user viewers prior to implementation will also help to avoid common pitfalls associated with SG use within education. In this study, incorporating validated tools to assess the SG supported the design of DOSE by providing a quantitative element of feedback in tandem with students' qualitative responses. Overall, DOSE was well received, and students reported a positive experience. However, it is essential to be cognizant of external factors that may impact student feedback such as upcoming exams, a lack of familiarity with clinical content in the SG, and a high student workload (e.g., coursework). These considerations are also relevant when assessing whether a cohort is an appropriate sample at that time for recruitment onto a SG study.

## Summary

This study has provided evidence that DOSE has met two key criteria that reflect successful SG design whilst demonstrating the overall playability and acceptability of the model. The usability of DOSE was demonstrated beyond the initial target audience of pharmacy students and was perceived as a useful model among nursing students. Therefore, this study provided preliminary evidence that SGs can be used as a supplementary educational tool for healthcare students. Future work will focus on further validation of DOSE as well as incorporating an impact assessment to identify the potential value of DOSE as part of both the pharmacy and nursing curricula.

## Disclosure(s)

None.

## Declaration of Cpmpeting Interest

None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cptl.2021.06.023.

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