Development and evaluation of an educational game to support pharmacy students

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Abstract

Introduction: Pharmacy students in the United Kingdom (UK) need to efficiently navigate the British National Formulary (BNF), a standard medicines reference source. “Pharmacy Challenge” is a web based prototype game based on the BNF. This research aimed to evaluate the game in terms of design, content and impact on students’ performance and confidence.

Methods: Evaluation comprised three phases: implementation, perception and impact of a serious game. Game design and evaluation methods were modelled using adapted elements of the RETAIN framework. Qualitative and quantitative questionnaires were utilised to assess students’ perceptions of the game and its role in their education and to evaluate changes in confidence and performance experienced by students after playing the game. Quizzes were developed to determine changes in performance through comparison of scores before and following game use.

Results: The questionnaire evaluation (n=152) found students’ confidence increased significantly (p<0.05) in: speed of using, knowledge of BNF sections, extracting information and knowing where to look for the answer. Students (88%;106/120) felt they had learnt something new, 86% (103/120) felt that it reinforced their learning. A significant (p<0.05) increase in pre and post BNF quiz marks was observed (n=33).

Conclusions: Statistically significant improvement in students’ perceived confidence was noted. The study identified design elements such as the need for a simple interface to encourage engagement.

The prototype has undergone a design transformation based on the feedback provided and is now released under the name “DOSE” with a bank of 300 questions, improved graphics, a leadership board and medals.

Keywords: Educational game; serious game; game design; online education; pharmacy education; information skills.

Conflict of interest: None

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Introduction

Contextualising “Serious Games” in Pharmacy Education

Interest in educational games referred to as “serious games” has significantly increased in the last decade.[1] Unlike the traditional definition of games as forms of entertainment, Serious Games (SGs) primarily focus on education and training.[2,3] A 2015 review of educational games introduced as part of US pharmacy curricula identified 11 games from 13 studies published between 1995-2013.[4] The format for each game varied across several components including; the number of participants, use of a staff facilitator and their objectives. However, some key commonalities were identified such as the use of PowerPoint as part of the activity, student collaboration and the application of curricular knowledge. The review highlights advantages, with cited engagement from students, improved confidence and promotion of peer interaction. In contrast, the authors note a key issue throughout the review with respect to increased staff workload for both game development and facilitation, which proved to be a problematic aspect of implementation. The review also underlined the lack of evidence for assessing the role of educational games as a method of learning within pharmacy curricula. Despite this, Aburamha and Mohamed[4] highlighted the potential for educational games as a learning tool in pharmacy education but describe the need for collaboration between educators and designers to optimise overall game development and overcome previously cited barriers to implementation. Breuer and Bente[5] define SGs as digital learning tools and emphasise the need for SGs to effectively deliver both educational and entertainment elements to match the fast-growing digital game market. Based on the aforementioned, there is still a gap in evidence related to not only SG development within pharmacy curricula but also the importance of designing more comprehensive tools that can deliver quality learning outcomes within a digitally-driven field.[4,5]

Development of “Serious Games”

To develop a successful educational game, emotional, social and cognitive factors must be considered and motivation must be identified.[6] For example, gender differences have been found in the participation in, and reason for playing, games.[7,8] Research by Rose[9] and Petitdit Dariel et al[10] has shown that each learner develops at their own specific rate, which can make tailoring a game challenging. Frameworks, such as the Relevance Embedding Translation Adaption Immersion and Naturalization (RETAIN) model, have been developed to help overcome the limitations within educational games.[11] More specifically, RETAIN seeks to identify how well a measure reflects what is taught, otherwise known as instructional validity. Based on RETAIN, embedding curricular content

within an SG narrative supports student engagement and as a result may encourage both active learning and knowledge retention[9,12]. Therefore, SG narrative development needs to take into account the potential for students to achieve relevant curricular learning outcomes that may result in motivating them to immerse fully within the SG, thus resulting in enhanced self-regulated and productive learning.[6,13] When utilising the RETAIN model, game development can lean toward designs that promote knowledge transfer, as demonstrated by Campbell et al[14], making RETAIN a useful tool for implementing SGs within an educational curriculum.

"Pharmacy Challenge" as a "Serious Game"

Health-related SGs are on the rise for junior doctors, nurses and pharmacists.[15,16] In 2012, Kingston University conducted a needs-assessment to identify a successful design for an educational game for pharmacy students to improve their knowledge and retrieval of information in the British National Formulary (BNF): the BNF is a standard reference source in Great Britain (GB) for all healthcare professionals involved in the prescribing, supply and monitoring of the use of medicines. Social interaction through competition/collaboration and feedback were identified as important aspects of an educational game.

Following the needs assessment, a prototype called "Pharmacy Challenge" was designed as a web-based digital SG, accessible on both PC and mobile devices. The prototype was designed with a focus on the curricula for students in their 3rd and 4th year of the MPharm degree. Years 3 and 4, referred to as Level 6 and 7, focus on the development of students' clinical knowledge and ability to extract information to make informed decisions regarding patient care and disease management. For students to qualify as pharmacists after university, they must sit a professional registration assessment, which includes completion of clinical multiple-choice questions under timed conditions. To reflect this and the examination format used currently at our university, students were given 3 minutes to answer multiple-choice questions (Appendix 1) based on clinical content from the BNF, with additional points awarded for answers given in less than one minute. In all seminars, workshops and practicals the BNF is used as the main source of information for students during case-based learning and Objective Structured Clinical Examinations (OSCEs), where students' knowledge and clinical skills are assessed. The purpose of the game was for students to acquire as many points as possible by giving correct answers to each question using the BNF. To reflect student confidence in

their use of the BNF for finding the relevant information, players were asked to decide how many points (out of 50) to bet on that answer. If the correct answer was given, the points were doubled. Incorrect answers did not incur a penalty.

There were 20 rounds in each game. The game initially consisted of a bank of approximately 130 questions and offered feedback with respect to BNF information if the wrong answer was given e.g. "See Chapter 3, Sub-section 3.2 – Thromboembolism". Players could complete the game individually (single-player mode) or create teams via the online browser to answer questions together (multi-player mode) which meant increasing the potential to earn extra points through the betting feature. The game was not a mandatory activity as part of the curriculum, but rather a tool that sought to support students' confidence and use of the BNF, as well as potentially improving clinical knowledge associated with Level 6 and 7 curricula. Therefore, the learning objectives of the game were to enable students to effectively utilise the BNF for clinical decision making, to enhance students' engagement with the BNF outside of the curriculum and to indirectly optimise their clinical knowledge in relation to disease management. Furthermore, the game provided the opportunity for students to practise multiple-choice clinical questions under timed conditions as additional preparation for exams.

The aim of this research was to evaluate the "Pharmacy Challenge" game in terms of design, content and impact on students' performance and confidence.

Methodology

RETAIN Framework

An essential part of the pharmacy challenge development process involved the implementation of the RETAIN model for each iteration of the SG. As discussed, RETAIN seeks to identify how well a SG achieves its intended objectives by analysing the 6 key domains as part of the development framework. The RETAIN elements were adapted into larger concepts from which items for the study were then derived, these have been demonstrated in Table 1.

Evaluation of the design and content focused on items that explored the concepts of Relevance, Immersion and Naturalisation e.g. motivation to play the SG, motivators for playing, perceptions of SG content and barriers to engagement. Evaluation of changes to confidence, as well as subjective and objective improvements in performance, were explored through the concepts of Embedding, Transfer

and Adaptation e.g. recognition of curricular content within the SG and transfer of knowledge to a similar context outside of the SG.

Phase 1 – Prototype development and pilot evaluation

A questionnaire was developed to evaluate both the design and content of the game, as well as perceived improvements in performance (Appendix 2). The questionnaire was provided to students (n=70) following a brief pilot study in 2013 using the first iteration of the game prototype.

Face validity was confirmed using five students, who were not participating in the research. Hard copies of the questionnaire were distributed in class a week after the game's release. The data received was entered into SPSS19®[17]. All data was anonymous except where students gave their university ID number to indicate they wanted to know more about the project. Data was analysed descriptively using SPSS19®[17] and Microsoft Excel®.[18]

Phase 2 – Revised prototype implementation

A. Evaluation of design and content

Following feedback from Phase 1, minor changes were implemented to better support the design, content and playability of "Pharmacy Challenge". As part of the iterative review process, a revised questionnaire was designed to capture students' perceptions of design features, the usability of the game and ideas for future development following the prototype changes in a wider prototype release in 2014. This was collated in Section 1 of the questionnaire. Section 2 consisted of items relating to students' confidence and perceived improvement in performance. Demographic details were captured in Section 3 (Appendix 3). The questionnaire was validated by three students not participating in the research.

B. Evaluation of perceived improvement in confidence and performance

Questionnaire items were designed to examine how the use of resources such as the BNF, and familiarisation of clinical knowledge embedded in the curriculum might impact students. The questionnaire was distributed to all Level 6 and 7 pharmacy students (n=256) via the university's virtual learning environment (Blackboard®). A hard copy of the questionnaire was also made available to increase the response rate. Students were invited to play the game and then complete the

questionnaire. Completed questionnaires were only accepted if the student had provided their unique university registration number to prevent duplication. Following feedback, students were able to access “Pharmacy Challenge” for an extended duration of 3 weeks compared to Phase 1 with only 1 week of accessibility.

Data received was entered into Microsoft Excel®[18]. The data was analysed by question initially then by sub-analysis. Descriptive statistical analysis was conducted, and *t*-tests were used to test for statistical significance.

Phase 3 – Objective impact on performance

“Pharmacy Challenge” was designed to improve students’ information skills and use of resources such as the BNF. However, it was also expected that exposure to clinical content, aligned with the Level 6 and 7 curricula, would potentially influence student performance outside of the SG context. To measure impact, two quizzes based on the BNF were designed by the researchers to investigate competence in using the BNF (Appendix 1) and clinical knowledge expected of students in Levels 6 and 7. The two quizzes were designed to be implemented in a timed classroom setting, with the aim of reflecting a standard examination scenario unlike the format of students playing the “Pharmacy Challenge” game in a timed, but open environment. Students supplied with a quiz both before, and after completing the game providing data for a pre and post-analysis. For the quizzes, 24 multiple-choice questions were developed. From the 24 questions, 16 were selected and divided evenly between the pre and post quiz, hence students could score a maximum of 8. The questions had 5 potential answers, with one correct response. Topics chosen for the questions were varied and focused on interactions, indications and common side-effects associated with medicines. Due to timetable restrictions, only Level 6 students were available to participate in Phase 3 of the study. Clinical teaching staff reviewed the quizzes’ content to confirm suitability for Level 6 students.

One quiz was administered to Level 6 pharmacy students in class before the game was released. The students were given 10 minutes to answer the questions using their BNF. Three weeks after the game’s release, the second quiz was administered under the same conditions. The scores for each quiz were anonymously recorded and *t*-tests were carried to test for statistical significance with $p<0.05$ being used as the indicator of significance.

Ethical approval was received from the Kingston University Faculty Research Ethics Committee (1213/045).

Results

Phase 1 – Prototype pilot development

A. Design, Content and Playability

The majority (80%; 56/70) of the students completed the questionnaire. The demographic characteristics of responders are presented in Table 2.

A large proportion (80%; 45/56) had played the game. With respect to content, the majority (89%; 40/45) thoroughly enjoyed playing the game describing it as “fun and enjoyable”, “brilliant” and “amazing”. Most (84%; 38/45) wanted to play the game again. Reasons given for playing the game were; knowledge of an upcoming test in class, to improve their BNF skills and some were “just curious”. The main reason given for not playing the game was; “timing”. The game was only accessible for a week; some students had placements and assignments to complete and revision for mid-module tests. Overall students found the game “very helpful” and felt “the game was well designed” and “amazing”. Others concluded; “great game but … room for improvement” and “good fun but had technical problems”. The majority (93%; 42/45) felt a game with the same concept but for different modules would be beneficial. One of the most popular suggestions was to add more questions to the game with others suggesting, “Faster speed, more questions and easy access”, “answers at the end of the quiz”, “No betting required” and “More calculations”

When examining SG design elements, approximately a third of the students (31%; 14/45) favoured the “time challenge” feature the most. Students commented: “I am quite slow so it forced me to be aware of my time” “made me have to be faster with BNF” and “it helps me complete tasks within time”. The second most popular feature (24%; 11/45) was the “questions”. Students found them “interesting, it actually makes me want to find the answer” and “relevant to what we are expected to know at university”. They also liked that “questions were from different parts of the BNF which enabled me to learn new things”. About a fifth (22%; 10/45) enjoyed the single-player mode.

When asked about the least liked feature, 22% (10/45) said the “multiplayer mode”. Some reasons for this were: “Too much time needed to wait for all the players to be ready”, “no clear

instruction in how to use it for example; like the fact that both parties need to be live at the same time" and "took too long to respond". A similar percentage of students (20%; 9/45) stated the "betting" feature. Some reasons for this were: "I wasn't very good at it", "Difficult to select the exact amount of betting by using the finger on the IPad" and "time consuming".

Feedback from the 10 students who did not play the game included "wanted more access time to play the game" and "easy access to the game" as some browsers that were suggested did not open the game. However, 70% (7/10) of these students felt the game could have a positive influence on their performance. The frequency of playing the game ranged from once a week (18%; 8/45) to more than 10 times (4%; 2/45). The modal response was 3 to 5 times per week (38%, 17/45).

B. Perceived improvement in performance

With regards to improvement in academic skills, the modal response was "helped but not a lot" (31%; 14/45) however the game helped the majority (93%; 42/45) to some extent. The things they had learnt were: "New sections of the BNF, I wasn't aware of and managed my nerves when searching for an answer", "to time myself more appropriately" and "about some new drugs I didn't know before; how to get information faster". Male students felt the game improved their pharmacy skills more than females (p=0.019) as shown in Table 3.

Perceptions of the game are summarised in Table 4.

Phase 2 – Revised prototype implementation

Following phase 1 and in response to student feedback, the following changes were made: instructions on use of the game prior to implementation, an extended duration for players to access the game and directing students to suitable internet browsers in order to avoid previously cited technical issues and formatting e.g. loading game features.

A. Design, content and playability

The response rate to the questionnaire was 60% (152/256), a further eight were returned incomplete. The demographic characteristics of the respondents are shown in Table 5. Of the 152 respondents, 79% (120/152) had played the game. 91% (118/120) of respondents would play the game again. Feedback on the design and playability was similar to Phase 1.

When considering game development students highlighted more BNF questions (71%;85/120) followed by calculations (63%;76/120) and 'responding to symptoms' (48%; 58/120) type questions as features to improve content. Further design suggestions included: inclusion of a progression bar; the ability to save progress; affiliation of identification number with score; flexibility to choose the number of questions to answer.

The questionnaire identified that a majority of students (86%;103/120) felt that the questions in the game reinforced their learning, while 88% (106/120) felt that they had learnt something new from playing the game. "The importance of reading [the] beginning of sections (in the BNF) to help aid in decision making." was highlighted. Others felt that the game highlighted important sections of the BNF, "some sections in the BNF have now been familiarised with the use of the game". A number of respondents strongly agreed/agreed (65%;78/120) that the "Pharmacy Challenge" game motivated them to do well in their studies. Overall, 88% (106/120) felt that the game had aided their learning.

Over half of respondents (52%;62/120) agreed the feedback given was helpful as "it allowed you to look at the answer again, to challenge yourself to find the correct answer." However, 12% (14/120) felt that the feedback was not helpful and it "would be better to give the extract from the BNF, ability to view the questions you get wrong like a summary so that you can look it up later for revision.", or to "display answer for a question if wrong instead of just the BNF section," "as there are questions (that) even with the feedback I still don't know the answer to".

B. Perceived improvement in confidence and performance

The majority of respondents (89%; 135/152) felt that an online game can have a positive influence on performance. On a scale from 1 to 5, with 1 denoting 'a lot' and 5 'not a lot', 51% and 52% of males and females respectively rated improvements in their ability to use the BNF as 1 and 2 with 24% and 27% being neutral respectively.

Similarly, the majority (55%; 66/120) of respondents felt their overall confidence in using the BNF had increased since using the game, with just 17% (20/120) stating their confidence had not improved (points 4 and 5 on the scale) and this could be influenced by the realisation of the speed required to answer a question; "I am slow" and "I need to speed up". A student summed up their confidence, "I first would bet less but was surprised my answers were correct, so I started betting with more

confidence." Confidence was shown to increase significantly in all aspects of using the BNF as shown by the increase in the rating score of 1 or 2 (most confident) in Table 6.

Phase 3 – Objective impact on performance

Sixty students participated in the quizzes with 33 taking part in both quizzes who were included as part of the performance analysis. When comparing scores from the pre and post quizzes following the implementation of the game, there was a significant increase (p=0.87 x 10^{-4}) incorrect answers with the mean score rising from 4.4 to 6.2 out of 8 possible marks. The majority (81%; 27/33) of students improved or maintained their score after accessing the game.

Discussion

Design, Content and Playability

Active learning results in an improvement in knowledge retention.[9,12] This coupled with the understanding that student motivation drives learning[16], plays an important role in conceptualising and designing methods to support students as part of academic curricula. Educational games offer an alternative approach to both broaden teaching styles and address the range of learning needs amongst students.[19] "Pharmacy Challenge" was rationalised as a digital SG, with the aim of overcoming obstacles presented by traditional educational games in pharmacy curricula[4] and as a step away from classic didactic teaching methods, which often lack accommodation for different learning styles.[20] "Pharmacy Challenge" provided students with a digital platform outside of the lecture hall, and hence an opportunity to learn in a non-threatening environment, which may support self-regulated and productive learning as discussed by Connolly[6] and Dominguez[13]. These findings were supported across both iterations of "Pharmacy Challenge", with the majority of students confirming that they felt an online game can have a positive impact on performance. Further evidence of self-regulated learning was demonstrated, with almost all respondents agreeing that they would play the game again. This may be potentially impactful for students in achieving learning outcomes as part of the curriculum by encouraging engagement with the BNF outside of compulsory sessions.

To better understand the impact of "Pharmacy Challenge", questionnaires were developed to examine design, content and perceived benefit to students. Questions were developed with a focus on the RETAIN model, examining elements of the framework with the aim of supporting SG development and implementation. Students rated the game positively for its content and purpose with the majority

feeling the game had aided and reinforced their learning. This response from students is suggestive that criteria for 'Adaptation' and 'Immersion' had been met to some extent, building upon existing knowledge derived from the curriculum in an interactive manner. Another aspect of interest is the level of difficulty introduced by the SG. Martin et al[21] comment that students can be deterred by overly difficult content in academia. To overcome this, it is important to ensure correlation between both curricular and SG content, an element reflected in the RETAIN framework ('Embedding'). Overlap supports the relevance of the content as described by Gunter[11], which may potentially improve student engagement irrespective of difficulty. Some evidence to support this was demonstrated in Phase 2. Despite the majority of students finding the game content challenging, 88% felt they learnt something new, which in most cases was related to working under a time constraint and to learning about different sections of the BNF. Content was developed from the BNF in correspondence with Level 6 and 7 curricula. This may have been a factor in the relevancy of SG content and student stimulation irrespective of pressures such as the time limit and question difficulty.

Numan[22] describes how time constraints, specifically within examinations, can negatively impact performance at the undergraduate level, often as the result of stimulated student anxiety. Interestingly, the "time-challenge" was deemed as the main beneficial feature of "Pharmacy Challenge" by students. They felt the game "forced" them to be aware of their time. This positive response implicates a number of potential factors. Firstly, delivering clinical examination material via a digital SG format may dissociate students from a perceived threatening environment.[6,13] Secondly, digital SGs have been shown to enhance visual attention, perhaps distracting students from time-constraint related anxiety.[23] Thirdly, having a small window of timed engagement with each question may motivate students to focus on the immediate activity. This last suggestion was investigated using a popular puzzle-based game played in South Korea "ANIPANG", with each game lasting only 1 minute.[24] The study demonstrated that the shorter the time period, the greater the level of players' loyalty. More work is required to understand whether introduction of clinical content via SGs under timed conditions can help alleviate student test-related anxiety.

The single-player and multi-player mode gave the game diversity as some students preferred to learn individually and others in a group. The literature[25,26] shows students prefer working in a group, however in this study this feature was disliked the most despite the evidence demonstrating multi-player games to be more engaging and fun.[27,28] In "Pharmacy Challenge" players were required to

place their bets and wait for everyone to answer before results were shown. Marsh[29] describes how digital SGs with a focus on fast interactions are prone to player impatience where the design is deemed to include unnecessary waiting times. The multi-player format of "Pharmacy Challenge" proved to be too slow, resulting in reduced playability and player satisfaction.

Player betting added an interesting dynamic to the design of "Pharmacy Challenge". It was proposed that this feature would reflect student confidence and encourage informed attempts at answering questions with the incentive of increasing the overall score from the game. SG competitive scoring has been shown to improve motivation and engagement, which in turn contributes to active involvement from players.[30] As already discussed, active players are more likely to retain knowledge from SG interaction.[12,16] The results did not reflect this however, with betting being described as one of the least favourite features. Students stated it was time-consuming and hard to use, potentially reducing SG immersion, which is an essential factor in successful SG design with respect to the RETAIN model.[11]

Perceived improvement in confidence and performance

The preliminary feedback showed that using a web-based game can enhance students' learning experience and make it more fun while improving their learning efficacy. It was interesting to note that males felt that they had improved pharmacy skills more than females (76.9% vs 56.2%) though with such small numbers the significance at this stage is unknown. Tsai[7] also found females considerably less positive in their attitudes towards digital games, which may explain their perceived level of improvement and confidence in skills provided by participation in the game.

Students found the featured feedback helpful in terms of improving performance, however many students cited that they wanted to see the correct answer, reflecting this generation of learners, who require an instant response and satisfaction from a tool.[25,31] Feedback was provided if an incorrect answer was given in the form of the BNF section number where the answer could be found. Whilst research by Lam et al[32] shows that performance is increased over time with more feedback received, students must take this feedback and learn from it. Vitasari[33] shows that students would become complacent and not partake in the game to its full potential if the correct answer was provided instantly. This would defeat the basics of blended learning through self-directed engagement, in this

case navigating the BNF.[16] One suggestion was having an optional "hint" button in the game that would require players to sacrifice some of their points if used.

When students were asked to rate their confidence before and after playing the game, confidence was shown to have significantly increased in terms of: speed of using the BNF, increased knowledge of sections, ability to extract information and knowing where to look for the answer (p<0.001). Both this study and work by Boctor[25] and Knight[34] have shown that SGs can build confidence and knowledge such as in nursing registration exams and in major incident triage training respectively. Overall confidence in using the BNF had increased, with 55% citing this. Students experienced the recognition that there were sections in the BNF they had now become familiarised with by using the game. As the students are performing a real-life activity whilst playing the game, it is hoped that their improved ability will transfer into their everyday work when accessing the BNF.

Objective impact on performance

Students felt that the "Pharmacy Challenge" game had improved their use of the BNF with performance showing a significant improvement (p=8.7x 10^{-5}). Whilst the game could be seen to have improved the scores in the post-game quiz, other factors should be considered, such as repetition of playing the game, the knowledge that there would be a quiz and the expectations that come from this.[25,35] Furthermore, these results should be treated with caution due to the small sample size.

Areas for Game development

The "Pharmacy Challenge" game was described as having a poor interface and complicated to play by some students, which discouraged engagement. The additional need of learning how to play the SG also deterred student uptake. When considering the RETAIN model[11], full immersion requires that the elements of gameplay should not impede the pedagogic element. In order to encourage more students to use the game, it needs to be made simpler and more inherent to play. However, it should be noted that over 90% of students felt that it would be beneficial to have the same game for different modules, showing the overall acceptability of the concept. All feedback on the design, ease of use and additional content will be reviewed in the future development of the game.

There are some limitations around asking respondents to assess their own performance. Whilst students felt that their confidence had increased, and answered the question accordingly, the data collected was anonymous and therefore there is no way of attributing actual performance to perceived

performance. To assess confidence levels and differentiate between gender and age, further research is needed, as the sample size is small and biased to females and younger age. In terms of objective improvements in performance, the study had a small sample size, hence these results should be treated with caution.

There is no control group to enable a comparison with other methods of training students how to use and search the BNF effectively. However, this game was intended to be an addition to other methods of teaching and not as a replacement. As noted by Squire[36] games are not intended as a replacement for traditional teaching methods, but to motivate students to return to the traditional resources to improve their performance in the games.

Conclusion

The purpose of this study was to evaluate the design, content and playability of the game. The student response was positive but provided valuable feedback in terms of improvement and development of the "Pharmacy Challenge" model, especially regarding format aspects that hindered playability. In terms of perceptions on confidence, students felt that they had gained confidence from using the game. This finding was similar to perceived improvement in their ability to use the BNF, which was also reflected in the objective improvement in performance using the pre and post-game clinical quizzes. Overall, the concept was well accepted with "Pharmacy Challenge" providing an alternative digital learning platform, which students indicated they would like to see implemented for additional clinical modules and topics.

Following feedback and support from students, the prototype has now undergone a design transformation regarding design and is now released under the name "DOSE" with a bank of 300 questions. Developed features include improved graphics, a leader board and medals. An evaluation of this will be reported elsewhere.

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Appendix 1

BNF quizzes

Quiz 1

1) Which one of the following drugs causes a change in a patient's thyroid functioning when taking levothyroxine? BNF: Appendix 1: Interactions
    a. Warfarin
    b. Amitriptyline
    c. Carbamazepine
    d. Propranolol
    e. Simvastatin
2) When using Ergot derived dopamine receptor agonists what aren't patients monitored for to check for Fibrotic reactions? Section 4.9.1
    a. Persistent cough
    b. Chest pain
    c. Cardiac failure
    d. Dysponea
    e. Nocturnia
3) If a 75kg female was given Amiodarone tablets for the first time, how many 200mg tablets would she need for a month's supply? Section 2.3.2
    a. 28
    b. 56
    c. 42
    d. 49
    e. 112
4) If a patient was taking 400mg of Sulpiride daily, and they needed to change to Chlorpromazine, what dose would you give daily? Section 4.2.1
    a. 200mg
    b. 400mg
    c. 75mg
    d. 25mg
    e. 100mg
5) Over a period of a week what would you expect the haemoglobin concentration of an anaemic to increase by? Section 9.1.1
    a. 1-2g/litre
    b. 7-14g/litre
    c. 20g/litre
    d. 2g/100ml
    e. 7-14g/100ml
6) Which eye drop would you use to treat corneal ulcers? Section 11.4
    a. Chloramphenicol
    b. Azithromycin
    c. Ciprofloxin
    d. Levofloxin
    e. Ofloxacin
7) Which one of the following is not a severe adverse effect from methotrexate? Section 10.1.3
    a. Dark urine
    b. Bruising
    c. Cough
    d. Shortness of breath
    e. Headaches
8) What dose of prednisolone orally would need to be given to treat a 22kg child daily for treatment of life threating acute asthma? Section 3.1

a. 22-44mg
b. 22-40mg
c. 40-50mg
d. 88mg
e. 50mg

9) Which of the following is an aldosterone antagonist? Section 2.2.3
a. Triamterne
b. Inspra
c. Amiloride
d. Bumetanide
e. Furosemide

10) Which of the following is a short acting human insulin? Section 6.1.1
a. Apidra
b. Insulin Glargine
c. Novomix 30
d. Levimir
e. Lantus

11) The antiplatelet effect of clopidogrel is reduced when it is taken with:
a. Fluoxetine
b. Etravirine
c. Prasugrel
d. Cimetidine
e. Moclobemide

12) Which of the following classes of drugs can impair cerebral function and precipitate hepatic encephalopathy?
a. Non-opiod analgesics
b. Opiod analgesics
c. Insulin
d. Stimulant laxatives
e. Osmotic laxatives

Quiz 2

1. Which of the following is a side effect of Alteplase?
a. Headache
b. Diarrohea
c. Bleeding
d. Bruising
e. Blurred vision
2. Which of the following is the correct cautionary and advisory label for Malarone®?
a. Protect your skin from sunlight-even on a bright but cloudy day. Do not use sunbeds
b. Take with or just after food, or a meal
c. Take 30-60 minutes before food
d. Take with a full glass of water
e. Swallow this medicine whole. Do not chew or crush
3. Which eye drop would you use to treat Glaucoma?
a. Levobunolol
b. Lodoxamine
c. Tropicamide
d. Dexamethasone
e. Moxifloxacin
4. How much corticosteroid preparation is prescribed for application to the scalp?
a. 15-30g
b. 100g
c. 30g
d. 15g

e. 30-60g

5. Your patient is taking 20mg of Prednisolone tablets daily, how much Hydrocortisone (mg) would they need to take if you wanted to change their steroid?
    a. 20mg
    b. 5mg
    c. 100mg
    d. 80mg
    e. 16mg
6. Which one of the following anti-depressants is better tolerated?
    a. Clomipramine
    b. Trazodone Hydrochloride
    c. Moclobemide
    d. Agomelatine
    e. Fluvoxamine Maleate
7. Which oral contraceptive has Ethinylestradiol 35 micrograms and Norethisterone 500 micrograms in its dose?
    a. Logynon ED®
    b. Brevinor ®
    c. Mercilon ®
    d. Cerazette®
    e. Micronor®
8. What is the usual maintenance dose of Allopurinol in moderately severe conditions of gout?
    a. 300mg daily
    b. 300-600mg daily
    c. 100mg daily
    d. 100-200mg daily
    e. 700-900mg daily
9. Which class of drugs does Simvastatin have a black dot interaction with?
    a. Antidepressants
    b. Antidiabetics
    c. Calcium Channel blockers
    d. Cardiac Glycosides
    e. Oestrogens
10. Which one of the following is a symptom of severe acute asthma?
    a. Arterial oxygen saturation <92%
    b. Peak flow >50% of predicted
    c. Pulse <110 beats a minutes
    d. Pulse >110 beats a minute
    e. Hypotension
11. Levothyroxine has no interaction with which one of the following?
    a. Warfarin
    b. Glibenclamide
    c. Imatinib
    d. Gemfibrozil
    e. Orlistat
12. Which of the following antidiabetics is delivered by sub cut injection?
    a. Jentadueto®
    b. Forxiga®
    c. Amaryl®
    d. Lyxumia®
    e. Januvia®

Appendix 2

Phase 1 Questionnaire

Section A – Design & Playability

1. Did you play the 'Pharmacy Challenge' game?

Yes, If yes go 1.1 ☐ No, If no go to 1.2 ☐

1.1 If yes please answer following questions

a. What feature did you like most? Please select one from the feature list and explain why.

(Single player mode, Chat, Multiplayer mode, Betting, Competition, Questions, BNF reference, Time challenge)

……..

b. What feature did you like least? Please select one from the feature list and explain why.

(Single player mode, Chat, Multiplayer mode, Betting, Competition, Questions, BNF reference, Time challenge)

……..

c. What made you want to play the game?

……..

d. How many times did you play the game?

Please tick **one**:

Once ◯ Twice ◯ 3-5 times ◯ 5-10 times ◯ More than 10 times ◯

Please proceed to section B and C.

1.2 If you answered no to question 1, please answer following questions:

a. Please explain why you didn't play it.

……..

b. What would make you play it?

……..

c. Do you think such a game could have positive influence on your performance?

……..
……..

Please proceed to section D

Section B – Perceived improvement in performance & design improvements

Please fill out only if you played the Pharmacy Challenge game

2. How much did you feel that the game improve your pharmacy skills and/or knowledge?

Please circle a number from the range below.

1 2 3 4 5

(Not at all) (Moderate) (A lot)

3. What have you learnt from the game?

……

……

4. For future development, what changes would you recommend to support students' learning in the game?

……

……

5. Would you use the game again to help you with future work or exams?

Yes ☐ **No** ☐

6. Do you think it would be beneficial to have this same game concept with other modules?

Yes ☐ **No** ☐

<u>Section C – Perceptions</u>

Please fill out only if you played the Pharmacy Challenge game

SD - Strongly Disagree, D – Disagree, N - Neither Agree or Disagree, A – Agree, SA - Strongly Agree

Please tick one for each statement.

Statement	**SD**	**D**	**N**	**A**	**SA**
I really enjoyed playing the 'Pharmacy Challenge' game					
The game was very stimulating					
The pharmacy educational game motivated me to do well in my studies					

I learnt something new from playing the game					
The game was challenging					
The feedback the game provided was very helpful					
I found the game satisfying					
The goals/aims of the game were clear					
I would play the game again					
User interface was clear and well designed					
The game was boring / pointless					

7. Could you describe your overall perception of the game in one sentence?

……
……

Section D – Background information

This section of the questionnaire refers to background or demographic information. Your responses to this section will provide us with information that will allow us to compare groups of respondents.

Once again, we assure you that your responses to this section will remain anonymous.

A. Gender

Please tick **one**: Male ◯ Female ◯

B. Age

Please tick **one**: < 18 ◯ 18-20 ◯ 21-24 ◯ 25-30 ◯ > 30 ◯

C. Current student level

Please tick **one**:

MPharm 3rd year ◯

MPharm 4th year ◯

OSPAP 

Appendix 3

Phase 2 Questionnaire

Section 1: Perceptions of the game and future development

1. Did you play the "Pharmacy Challenge" game?
   a. Yes ☐ b. No ☐

   b. If not, why not? (free text)

---

   c. Do you think an online game can have a positive influence on performance?
      i. Yes ◯
      ii. No ◯

2. Please rate the features in the order that you liked (*1- liked the most, 8- liked the least)*

	1,2,3,4,5,6,7,8
Questions	
Time challenge	
Single player mode	
Chat	
Competition	
BNF reference	
Multi player mode	
Betting	

3. Are there any other functions you would like to see incorporated into the game? Eg progression bar, ability to choose how many questions are asked

---

4. Please rate the following topics in order of preference for future game development. (*1- Most preferred 5-least preferred)*

	1	2	3	4	5

BNF					
Law and Ethics					
Calculations					
Responding to symptoms					
Drug Tariff					

5. Are there any other topics you would like to see added to the game?

<u>Section 2: These questions look at how the game may have helped improve your use of the BNF</u>

6. On a scale of 1-5, how much do you feel the "Pharmacy Challenge" game has improved your use of the BNF?
   1,2,3,4,5 (1= A lot, 5=Not a lot)

   ☐

7. On a scale of 1-5, how confident do you now feel when using the BNF after playing the "Pharmacy Challenge" game?
   1,2,3,4,5,(1= A lot, 5=Not a lot)

   ☐

8. Please rate your confidence in the following before playing the "Pharmacy Challenge" game and after playing the "Pharmacy Challenge" game.

	1	2	3	4	5
Before playing: Speed at using the BNF					
After playing: Speed at using the BNF					
Before playing: Increased knowledge of BNF sections					
After playing: Increased knowledge of BNF sections					
Before playing: Confidence in extracting the information from the text					

After playing: Confidence in extracting the information from the text					
Before playing: Confidence in knowing where to look for an answer					
After playing: Confidence in knowing where to look for an answer					

9. What else have you learnt from the game?

---

10. Please rate the statements below in relation to the game:

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
The feedback the game provided was helpful					
The user interface was clear and well designed					
The instructions were clear on how to play					
The questions aided my learning					
The questions reinforced my learning					
The "Pharmacy Challenge" game motivated me to do well in my studies					
I learnt something new from playing the game					
The game was challenging					

11. Would you play Pharmacy Challenge again?
    a. Yes
    b. No

    If not why not?

Section 3: A little bit about you

12. Are you? (Please circle)
    Male/ Female

13. What is your age range?
    19-25 26-30 31-40 41-45 46-50 50+

14. What is your year of study?
    a. Year 3
    b. Year 4
    c. Ospap

Thank you for taking the time to complete this questionnaire.

Table 1

Table 2

Table 3

Table 4

Table 5

Table 6

Author Statement

The following table outlines the involvement of all authors for this manuscript.

Shereen Nabhani	Conceptualisation, methodology, validation, writing (review and editing), supervision, resources
Sonya Ishtiaq	Formal analysis, data curation, project administration, investigation
Victoria Ling	Formal analysis, data curation, project administration, investigation
Nicola Harrap	Formal analysis, writing (original, review and editing)
Maciej Dudzinski	Formal analysis, data curation, project administration, investigation
Darrel Greenhill	Conceptualisation, methodology, validation, writing supervision, software
Hope Caton	Conceptualisation, methodology, validation, supervision, software, resources
Nada Philip	Conceptualisation, supervision, software, resources
Joshua Wells	Writing (review and editing), visualisation
Reem Kayyali	Conceptualisation, methodology, validation, writing (review and editing) supervision, project administration