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Embedding retrieval practice in undergraduate biochemistry teaching using PeerWise

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Abstract

Retrieval practice is an evidence-based approach to teaching; here, we evaluate the use of PeerWise for embedding retrieval practice into summative assessment. PeerWise allows anonymous authoring, sharing, answering, rating, and feedback on peer-authored multiple choice questions. PeerWise was embedded as a summative assessment in a large first-year introductory biochemistry module. Engagement with five aspects of the tool was evaluated against student performance in coursework, exam, and overall module outcome. Results indicated a weak-to-moderate positive but significant correlation between engagement with PeerWise and assessment performance. Student feedback showed PeerWise had a polarizing effect; the majority recognized the benefits as a learning and revision tool, but a minority strongly disliked it, complaining of a lack of academic moderation and irrelevant questions unrelated to the module. PeerWise can be considered a helpful learning tool for some students and a means of embedding retrieval practice into summative assessment.

KEYWORDS

collaborative learning, higher education, learning communities, multiple choice questions, PeerWise, retrieval practice

1 | INTRODUCTION

Biochemistry can be a challenging subject to learn, due to the use of complex terms that are unfamiliar to students, the difficulty of visualizing specific biochemical processes and the volume of material students are expected to learn.[1–3] Retrieval practice is a powerful evidence-based teaching and learning method, wherein learners are prompted to engage in activities that "bring to mind" their pre-existing knowledge of a topic.[4,5] Common ways to do this include the writing/answering of questions, a strategy which has been consistently shown to improve student learning and transfer, when compared to the re-reading of notes or other text,[6,7] and the benefits are experienced independently of cognitive ability.[8] The benefits of retrieval practice are seen at every level of education, in authentic teaching environments as well as laboratory settings.[9] The neuropsychological basis for retrieval practice appears to be built on driving the retrieval of long-term memories while learning new, related information. Repetition of this process strengthens relevant associations between new and previously learned information while simultaneously weakening irrelevant associations.[9] Multiple choice

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questions (MCQs) are an obvious format for retrieval practice, and they are also a popular assessment tool in higher education (HE), due to large student numbers and the reliability of computer-assisted assessment and marking.[10] If students are involved in the construction of MCQs, then it can deliver retrieval practice and also allow students to achieve higher-order learning outcomes.[10,11]

PeerWise is a free, web-based platform (available from https://peerwise.cs.auckland.ac.nz/) that can be used to facilitate retrieval practice. It allows for student-centered question construction[12] and has been credited with enhancing desirable cognitive outcomes.[13,14] PeerWise allows the creation and publishing of MCQs related to individual courses or modules; questions can be text or image-based. Each question has one correct answer and up to four incorrect distractors and is in single best answer (SBA) format. Once questions are published, students can answer, rate the quality (zero to five stars, corresponding to very poor to excellent) and difficulty (easy, medium, or hard), and leave comments on questions authored by their peers. PeerWise can generate reports allowing academics to track engagement throughout the module, such as questions authored or users per day, as well as a breakdown of individual student usage statistics. Previous studies have demonstrated a positive correlation between PeerWise participation and examination score,[15–17] with McQueen et al. also showing that the benefits were more significant for lower-achieving students, which was attributed to the collaborative active engagement from peer feedback.[16]

Active learning strategies, which includes retrieval practice, upon which PeerWise is based, have been shown to have benefits to students, with the student-centered approaches helping to reduce failure rates,[18] improving module performance,[19] and increasing knowledge retention.[20] PeerWise should ideally enhance long-term recall of course content through two mechanisms: the generation effect, which occurs through the process of writing questions for other students to attempt and providing explanations for peers as to the rationale regarding the correct answer, and the retrieval practice effect while revising and answering other students' peer-authored questions.[21] The generation effect refers to the learning that occurs when students are actively involved in producing information, especially when coming up with explanations for answers. For example, in a study by Van Blerkom et al., participants were asked to author practice questions for a test[22]; performance in the test was shown to be highest when the practice questions most closely matched those in the assessment.

This case study involves a cohort of 246 first-year undergraduate biomedical science students across seven different degree programs studying a compulsory introductory biochemistry module. PeerWise was introduced as a summative assessment worth 5% of the overall module mark. Many of the studies cited above have investigated the effect of PeerWise on overall module outcome; here, we investigate whether there is a correlation between the level of engagement with the different aspects of PeerWise and associated student outcomes in the coursework, exam, and overall performance in the module.

2 | METHODS

2.1 | Context

Introductory biochemistry is a compulsory undergraduate module taught during the first 11 weeks of the first year on seven undergraduate degree programs (medical) biochemistry, (medical) genetics, joint honors biochemistry and genetics, applied medical sciences, and medical pharmacology. In 2019/20, the year of this study, it was assessed by a 100-question MCQ-based, time-limited unseen, closed-book exam (60%), coursework comprising three interactive lab worksheets from Learning Science (30%), with the remaining 10% coming from providing module feedback (5%) and engagement with PeerWise (5%). A minimum level of engagement was set for students to receive the 5% associated with PeerWise, requiring students to author two questions and answer, comment on and rate five questions with an "all or nothing" mark. The PeerWise platform was available from the first day of the module up until the day of the examination in January, ~5 weeks after the module's lectures had finished. The system was entirely student regulated, with no input from academic staff, with previous studies showing that students are well placed to judge the accuracy and quality of questions.[15]

2.2 | Guidance on using PeerWise and authoring MCQs

Students were introduced to the PeerWise platform and the underpinning theory of MCQs during a two-hour-long workshop in the first week of teaching. The workshop included a series of interactive exercises designed to teach students about common errors when authoring MCQs, as well as opportunities to practice writing and critiquing questions in small groups, which allowed students to start understanding how to provide feedback on questions.[23] Resources from the PeerWise website were linked to the virtual learning environment (VLE).

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2.3 | Data collection

Data from PeerWise were generated automatically and included daily usage statistics, such as the number of unique users and the number of questions authored and attempted. Individual student participation data, including the number of questions authored, answered, answered that agreed with the author, comments and ratings were also produced. These metrics were compared to module performance (coursework, exam, and overall module marks) to determine whether engagement with distinct elements of PeerWise was associated with improved performance across different elements of the module assessments.

To try and account for student ability, the marks achieved in the module in which PeerWise was implemented were compared against the mean marks achieved in three other modules that all students were enrolled on across the first year to produce a reference (benchmark) performance mark. The reference marks were then subtracted from the module marks to indicate whether students performed better or worse relative to their predicted performance level. Absolute and relative performance measures were correlated against PeerWise engagement.

To determine how big an impact engagement with PeerWise was having on overall student module performance, the cohort was divided into deciles based on engagement levels for each of the PeerWise engagement measures. The mean overall relative module mark was calculated for each decile, and the difference in marks was determined compared to the top decile to provide a scale of effect.

2.4 | Student perception

An electronic survey (Microsoft Forms) using 5-point Likert scale questions with further free-text responses was used to determine how the students perceived PeerWise. The survey was conducted in the last lecture of the module, with an electronic follow-up via email. Completion of the anonymous evaluation was voluntary; students were not offered any incentive to complete the questionnaires and were able to request that their PeerWise and module performance data were not included in the analysis at any point without penalty.

2.5 | Ethical approval

The study was approved by Swansea University Medical School's Ethics Sub-Committee (2019-0039).

2.6 | Statistical analyses

All statistical tests were carried out using IBM SPSS Statistics 26 using appropriate methods and a 5% level of significance.

We considered the correlation between the measurements of engagement and performance. Engagement marks included the number of questions authored, answered, answered correctly, comments written, and ratings provided while performance was represented by the student marks for the module as a whole, for this particular assignment and for related coursework. Since the distributions of these variables differed and were often positively skewed, we used a non-linear measure of correlation, Spearman correlation.

We then used the relative performance of the student (i.e., the difference between their mark in this module and the average (mean) of the other modules) as a metric. The upper limit of the effect size attributable to these correlations was estimated by comparing the top and bottom deciles to see how much engagement levels differed. Spearman correlation was used once again.

2.7 | Thematic analyses of free-text data

This was undertaken using inductive thematic analysis following the best practice standards for reporting qualitative data.[24] Participants were asked three questions: to identify any barriers associated with using PeerWise, that is, anything that made it difficult or not want to engage with the platform; what they liked about using PeerWise; and any changes they would like to see in the usage of PeerWise. Data were downloaded from Microsoft Forms and placed into a Microsoft Excel spreadsheet.

2.8 | Researcher characteristics

NF was a lecturer on the course, and TH was a final-year project student supervised by NF.

2.9 | Analysis

Both researchers coded the data manually using an inductive thematic analysis[25] to determine the frequency of keywords and identify themes in the student responses. Themes were then grouped together and checked for reliability through a process of reading and re-reading comments. This process was performed independently by both raters, who then reviewed and compared analyses to agree on the final themes. A third

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rater (ZZ) then reviewed the raw data and confirmed the themes and the selected quotes.

3 | RESULTS

3.1 | Usage summary

Daily usage statistics were tracked across the duration of the module, with peak usage observed the day before the module examination with 84 unique users authoring 82 questions and attempting 3226 questions. Other notable spikes in usage corresponded with periods around coursework submission deadlines in the module (Figure 1).

A total of 93% (229/246) of students registered for a PeerWise account and engaged in some capacity with the platform. Only students who engaged with PeerWise are included in the analysis. Summary statistics from PeerWise are shown in Table 1, detailing the total engagement with the platform across the different elements of PeerWise. Overall, average usage in all parameters far exceeded the minimum expected requirement to gain 5% for the assessment, with the mean quality of the questions rated at 2.97/5 (range 0–5).

3.2 | Module performance and PeerWise engagement

To determine whether engagement with PeerWise impacted overall module performance, the number of questions authored, answered, answered correctly, comments written, and ratings provided was correlated against the final module mark achieved as a composite of the exam and coursework marks. Spearman rho values indicated that there was a weak-to-moderate positive correlation between all aspects of PeerWise ($r_s = 0.338$–0.508, $n = 227$, $p < 0.001$) (Table 2).

To see whether PeerWise was having a positive impact on exam or coursework performance, marks for these individual components were correlated independently against the five different PeerWise engagement metrics. Exam performance was only weakly correlated

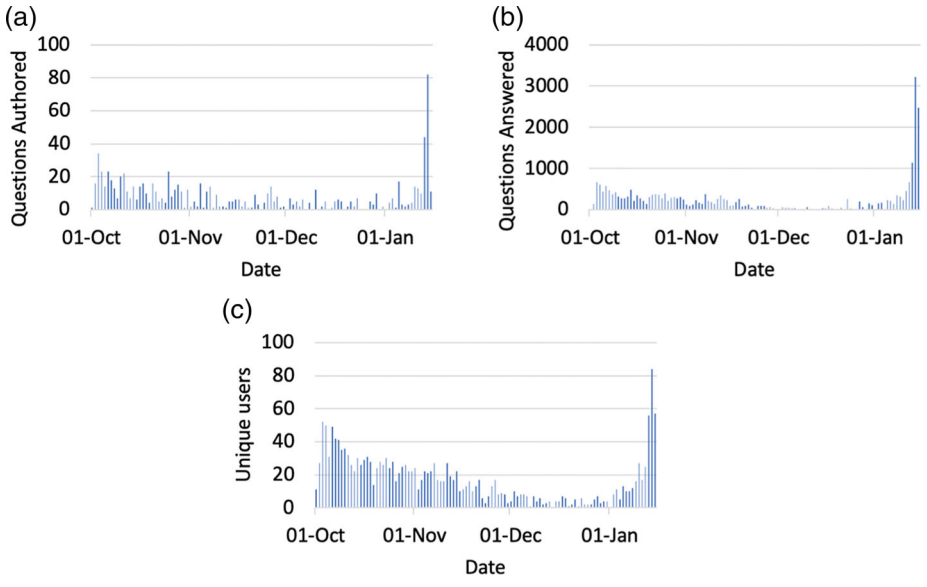

FIGURE 1 Daily usage statistics with each bar representing 1 day. (a) Number of questions authored per day, (b) number of questions answered per day, and (c) unique users per day. PeerWise usage peaked the day before the examination, with other spikes in usage at the beginning of the module and around coursework submission dates.

TABLE 1 Summary of student usage of PeerWise including the minimum required engagement levels to satisfy the assessment criteria, total, mean/median and range and interquartile range of questions authored, answered, questions attempted where the answer provided by the student matches the one provided by the author, comments written on questions and ratings provided.

	Minimum requirements	Total engagement	Mean (median)	Range (IQ range)
Questions authored	2	864	3.8 (2)	0–30 (3)
Questions answered	5	25,749	111.8 (42)	1–874 (124)
Correct answers	0	17,381	75.5 (28)	0–626 (81)
Comments written	5	4033	17.6 (6)	0–362 (7)
Ratings provided	5	21,646	94.0 (36)	0–772 (103)

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with questions authored and comments written ($r_s = 0.262$–0.371, $n = 227$, $p < 0.001$). However, there was a moderate correlation with questions answered, questions answered correctly, and ratings provided ($r_s = 0.412$–0.466, $n = 227$, $p < 0.001$). For the coursework, there was a moderate correlation with the number of comments written ($r_s = 0.418$, $n = 227$, $p < 0.001$) and weak correlations with other measures of PeerWise engagement ($r_s = 0.271$–0.327, $n = 227$, $p < 0.001$) (Table 2).

To try and account for student ability and determine whether the performance increases were due to engagement with PeerWise, these analyses were repeated, but for the module marks relative to the reference modules' mean marks. Results shown in Table 3 indicated that there was still a weak-to-moderate positive correlation for these referenced marks.

The student cohort was divided into deciles based upon engagement with PeerWise (using the five indicators of engagement listed in Table 3). Following this, the mean, standardized module mark of each decile was calculated and compared to that of the most engaged decile, to determine whether lesser engagement with PeerWise correlated with a lower module mark once student ability had been accounted for by the mark normalization and demonstrate the scale of effect. The results showed a generally linear decrease in performance as engagement levels fell with a difference of between 10 and 15 percentage points between the top and bottom deciles (Table 4).

Figure 2 illustrates the nearly linear relationship between engagement with PeerWise ranked by the number of questions authored and the overall mean module mark for each decile relative to the most engaged students. The figure shown is indicative of the results obtained for all comparisons, which displayed an R^2 range between 0.78 and 0.88.

3.3 | Student evaluation

A total of 87% (213/246) completed some or all questions in the evaluation survey. Figure 3 summarizes the survey responses. Approximately 75% of the students who completed the survey indicated that they rated the overall use of PeerWise as good to excellent (Q1), and this was also partially represented by student responses as to whether they felt the exercise had helped with their

TABLE 2 Correlation between engagement with different aspects of PeerWise and absolute performance in the module overall, exam, and coursework.

	Questions authored	Questions answered	Questions answered correctly	Comments written	Ratings provided
Module	0.338	0.461	0.508	0.477	0.462
Exam	0.262	0.417	0.466	0.371	0.412
Coursework	0.271	0.301	0.327	0.418	0.324

Note: $p < 0.001$ unless otherwise indicated.

TABLE 3 Correlation between engagement with different aspects of PeerWise and relative performance in the module overall, exam, and coursework.

	Questions authored	Questions answered	Questions answered correctly	Comments written	Ratings provided
Module	0.341	0.482	0.494	0.373	0.449
Exam	0.232	0.420	0.444	0.279	0.385
Coursework	0.272	0.168 ($p = 0.011$)	0.155 ($p = 0.019$)	0.257	0.194 ($p = 0.003$)

Note: $p < 0.001$ unless otherwise indicated.

TABLE 4 Mean relative performance (percentage points) decreases for overall module performance between most engaged and least engaged deciles for the different PeerWise engagement metrics.

	Questions authored	Questions answered	Questions answered correctly	Comments written	Ratings provided
1st–10th decile	−10	−14	−15	−13	−15

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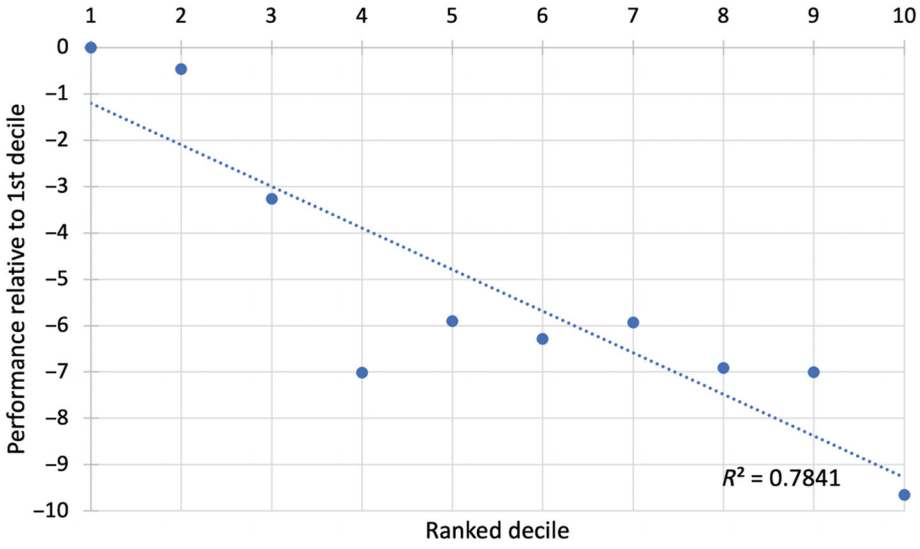

FIGURE 2 Relative mean performance between deciles compared to most engaged students ranked by number of questions authored.

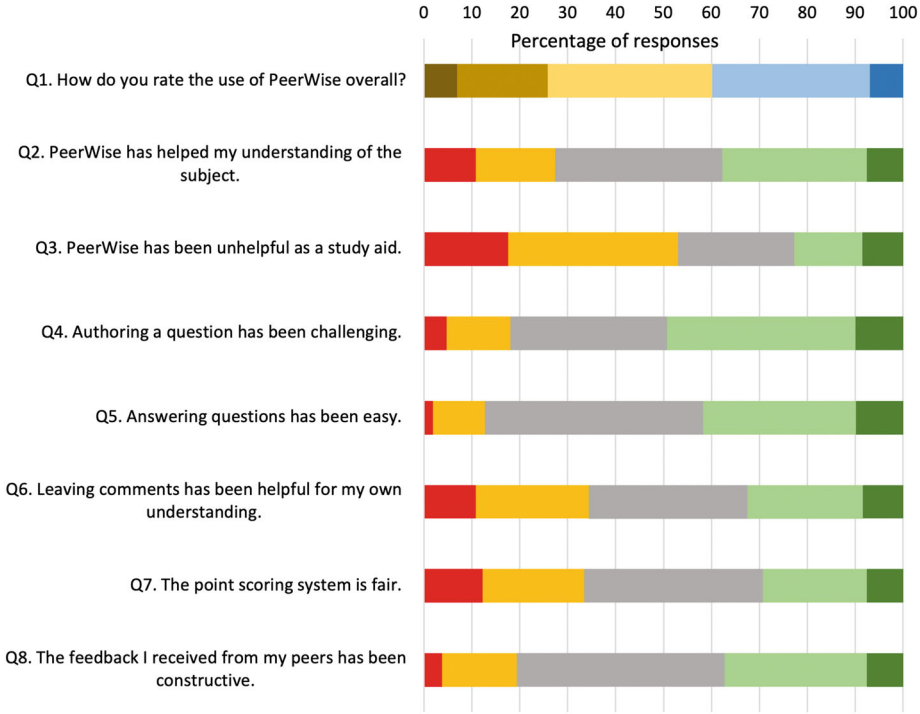

FIGURE 3 Stacked bar chart indicating the percentage of student responses to the anonymous questionnaire. Question 1 was rated poor (dark brown), fair (light brown), good (yellow), very good (light blue), and excellent (dark blue). Questions 2–8 were rated strongly disagree (red), disagree (orange), neutral (gray), agree (light green), and strongly agree (dark green).

understanding (~37% – agree or strongly agree) (Q2) and the percentage of students identifying PeerWise as being an unhelpful intervention (~23%) (Q3). The overall student perception was that authoring questions was slightly more challenging (~49%) (Q4) than answering questions (~42%) (Q5); however, students identified the activity as assisting their understanding with an appreciation of good constructive feedback from other students (~33% and ~37%) (Q6 and Q8). Whether the students felt that the point scoring system was fair (~38%) (Q7) showed a similar pattern of responses compared to whether students liked the use of PeerWise and found it useful (Q7 compared to Q1/Q2).

3.4 | Thematic analysis

3.4.1 | What barriers did students encounter when using PeerWise?

During coding, barriers were defined as any reason that students identified for either not wanting to engage or not being able to engage with the PeerWise platform. The response rate for this question was 163/227 (71%). The themes are illustrated with sample quotes and the percentage of quotes that were coded to that theme.

No barrier (21%) students generally just wrote "none," "N/A," or "no barriers."

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Frustrating challenges (34%) students found the authoring of questions challenging and were frustrated by questions that were off-topic or repetitive. Some students became disheartened if they were unable to answer questions that they found too difficult.

"Difficult to write good, original questions."

"Answering questions that are not in the syllabus/module."

'Difficult to come up with questions that have not already been asked."

"Found many Qs too difficult and not relative to my level of study! I found this intimidating."

Lack of understanding (17%).

"I don't understand how the website works and how to have access to the questions."

"At the beginning was a bit confusing using PeerWise."

Personal and technical barriers were also mentioned frequently *(15%)*, ranging from a lack of confidence in writing questions because others could see if they made a mistake, to a lack of time or motivation, or technical issues like poor WIFI connections.

"I didn't know what to ask or comment."

"The motivation to use it. It felt more like a chore and a competition than a learning aid."

"If the WIFI is a bit dodgy using PeerWise can be a bit hit or miss."

3.4.2 | What did students like about using PeerWise?

190/227 (84%) provided an answer to this question

Benefits (35%)

"To author a question requires you to understand what you are asking, giving a different medium of revision."

"That the same topic would come up in different forms of questions, further implementing that knowledge into my memory."

"Answering questions and being able to recognise my weak topics."

Social learning (14%).

"PeerWise allows students to work together and help each other. For example, they may have their own way of understanding so they can share that idea, or they can ask questions if they don't understand."

"The fact that you can interact with classmates and ask questions that you are unsure of the answers to. Also, leaving comments and getting feedback is helpful to improve and not repeat my mistakes."

Anonymity (5%).

"I like that it is anonymous, and everyone gets the chance to contribute. It allows shy people to ask questions."

User-friendly (14%) the ease of use of the platform was also popular with the students,

"The platform is very easy to use. Sharing questions I find is a great way to improve learning."

"Easy to use interface, has some good questions when it's something out of the box and challenging, makes me review content as part of ongoing revision."

3.5 | What changes would students like to see made?

120/227 (53%) of students responded to this question

Happy and enthusiastic (52%)

"I think it's fine how it is now."

"I would like to see it in different modules."

Lack of moderation (24%).

"There are no moderators, people upload questions that aren't fully relevant to the module."

"I wish the questions made by users to be reviewed by lecturers/staff to check whether they are relevant to the exam."

Discontinue (17%).

"Removal as a mandatory part of the module."

"I would prefer it to be optional and just for revision."

4 | DISCUSSION

4.1 | Benefits to students

PeerWise usage positively correlates with academic performance in exams and coursework on a first-year biochemistry module. Students showed high levels of engagement with the platform, particularly in the lead-up to the examination and around coursework deadlines (Figure 1), which supports previous findings among biochemistry students.[26] This approach has been shown to be a sub-optimal way to use PeerWise, as many of the learning benefits come from peer interaction,[12] which our study supports. In common with other studies of PeerWise across multiple different disciplines, the number of questions authored, answered, rated, and commented on was in excess of the minimum requirements of the cohort to satisfy the assessment requirements (Table 1).[15,16,27,28] Our findings confirm previous studies that have reported positive associations between PeerWise engagement and academic performance, not only in MCQ exams[15,27,29,30] but also in coursework[27] including when adjusted for prior ability.[16]

Interestingly, authoring questions showed a weaker correlation than answering questions, with similar findings having been reported from the use of retrieval

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practice in Medicinal Chemistry.[7] A possible explanation for this comes from the evidence around "desirable difficulty," where a task that requires a certain, desirable amount of cognitive effort can improve learning compared to tasks that are too easy or too hard.[31] This is supported by our data where a high proportion of students identified that authoring questions was challenging. It could be, therefore, that the strongest students benefit more from this element of engagement as they have a better grasp of the taught material (as suggested by McQueen et al.[16]), with weaker students struggling to come up with questions and suitable distractors either due to habitual lower engagement levels or a weaker knowledge base. Perhaps unsurprisingly, the correlation between questions answered correctly was slightly higher than that for just answering questions, demonstrating that the reinforcement of correct knowledge is advantageous, the extent to which students engage in retrieval practice has previously been shown to be predictive of performance in medical licensing exams.[32] The stronger correlations associated with providing comments and ratings compared to authoring questions are intriguing and suggest that even if students struggle to author questions themselves, they can engage well with those written by others, providing feedback, and judging the quality of the questions, which ultimately helps validate questions and build up the ranked revision repository. This supports the findings of McQueen et al.,[16] who suggested that a combination of reflective question setting and peer discussion of questions provided some of the learning benefits associated with PeerWise usage. It is likely that in addition to authoring questions, this evaluation of the quality of other students' questions as well as receiving feedback from other students also promotes deeper learning.[15] Particularly during a time when there has been a huge increase in the reliance on online and blended learning approaches due to the COVID-19 pandemic, the provision of platforms that allow students to develop a sense of community and engage with their peers in this manner is invaluable, even if communication is asynchronous and, in the case of PeerWise, can be anonymous.

Importantly, when the marks achieved for the overall module, exam and coursework were adjusted against three reference modules to account for the expected outcome, all the correlations between engagement and performance remained positive and highly significant (Table 3). Although the overall performance in the module is generally lower compared to the reference modules, the fact that there are still educationally significant correlations suggests that the improvement in performance can be attributed to the use of PeerWise, lending further support to its use as a tool for engaging students with their studies and enhancing understanding.

When comparing normalized outcomes against the levels of engagement, we observe an interesting trend, with the top engaging decile of students achieving an uplift in marks of between 10 and 15 percentage points compared to the lowest engaging decile (Table 4 and Figure 2). The generally linear trend, having accounted for student ability through normalization, does not suggest an optimal level of engagement with PeerWise, after which no further benefits are achieved.

4.2 | Student perception

Students were generally supportive of the use of PeerWise, recognizing the benefit as a learning and revision tool (Q2/3). To an extent, some students have also started to identify that the peer engagement aspect is important, suggesting that leaving comments can be helpful to their own understanding (Q6) and that the feedback they have received has been constructive (Q8). There were, however, a proportion of students for whom PeerWise did not work as a learning tool, being described by one student as "at best an annoyance, at worst a distraction." The biggest criticisms of the platform were that there was no staff moderation of questions and that some questions were off-topic. The PeerWise question bank was purposely left unmoderated to provide students with their own learning space and to allow them to feel comfortable making mistakes and learning from them, on the basis of prior research showing that students are well-placed to judge the accuracy and quality of questions for themselves.[15] Future guidance on the use of PeerWise should emphasize these points to students, and possibly to "seed" a small number of questions from the start, role-modeling the type and depth of questions required.

5 | CONCLUSION

The use of PeerWise is associated with deeper learning in a wide variety of subject settings. In this study, we make an additional contribution, showing that engagement with all the different aspects of PeerWise helps promote the overall learning benefits, which students see above their predicted performance levels.

CONFLICT OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, (NF), upon reasonable request.

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