Online Chemistry Crossword Puzzles Prior to & During COVID-19 - Light-Hearted Revision Aids that Work

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Abstract

This work explores the performance of online post-lecture chemistry crossword puzzles as revision aids for 132 first-year and 120 second-year undergraduate pharmacy students. The use of these puzzles as a form of remote active learning, was fortuitously evaluated immediately prior to and during the COVID-19 pandemic based on students’ online study behavior patterns, which captured some fascinating data on the frequency and timing of student online viewings. Students’ anonymous feedback responses were also evaluated.

Across 24 individual crossword postings, student-tracking data showed a total of 17,717 views; equivalent to approximately three views per posting by each student across the two different year groups, with evidence of some similarities and differences to student study habits when forced to work remotely. Furthermore, questionnaire feedback showed that around 80% of second-year students found the crosswords helpful and would welcome more, yet just over 50% of first-year students held these views, illustrating some year group differences. Interestingly, all students had similar opinions regarding their preferred online delivery resources should COVID-19 continue to prevent on-campus teaching.

In short, chemistry-themed online crossword puzzles were well-received when incorporated immediately prior to and during the COVID-19 pandemic. As many teaching institutions move away from a campus-based delivery, these effective and easy to prepare crossword revision aids should be considered by instructors alongside other online resources as they plan their teaching amidst continuing uncertainty.

Graphical Abstract



Keywords

First-Year Undergraduate / General, Second-Year Undergraduate, Organic Chemistry, Humor / Puzzles / Games, Aromatic Compounds, Chirality / Optical Activity, Heterocycles, Molecular Properties / Structure, NMR Spectroscopy, Reactions

Introduction

The original brief for this communication was to evaluate the use of online crossword postings as new revision aids to help support first and second-year pharmacy students with the chemistry aspects of their degree programme. As a UK instructor conscious of differing British and American terminology, revision aids in this context refer to learning resources that help students when reviewing content already covered on a course in readiness for a formal assessment, such as an exam. In the wake of the COVID-19 pandemic and the global lockdown of many university campuses the original remit of these crossword revision aids has remained in place alongside the major spike in educators’ interest in online delivery and remote learning resources.1 Due to the coincidental timing of this study, ahead of the pandemic, the author was able to compare online study behaviors prior to and during lockdown. In addition, student feedback questionnaires were adjusted in time to ensure that students’ online educational wish-lists could be captured after their inadvertent experiences as remote learners.

The positive impact seen from using educational games as light-hearted teaching tools has been widely reported over the years,2-6 with numerous descriptions of how tedious, time-consuming memorization tasks can be transformed into dynamic educational environments where student retention, motivation, participation and confidence are all improved.7-9 Using this more stimulating and enjoyable style of learning, these self-learning tools allow students to auto-assess themselves and as such, provide captivating, formative assessment opportunities to identify gaps in understanding while also reinforcing acquired knowledge.10-12

Since students, on average, register less than one-third of words spoken during traditional lectures,13,14 it is little wonder that instructors from across a broad spectrum of subject specialties have embraced the use of quizzes, table-top board games, card games and puzzles as effective and efficient active learning tools.9 Whilst this study focuses on the incorporation and evaluation of crossword puzzles as chemistry revision aids for first and second-year pharmacy students, previous studies have described the inclusion of crossword puzzles when teaching across many disciplines, including psychology,10 veterinary,12 sociology,15 pharmacology,16 biochemistry,17,18 biology,19 food science,20 nursing,21 dentistry,22 and medicine.23 For chemistry, this *Journal* first reported classroom crossword puzzles as far back as 1925, in which, as a twist to other similar studies, the teacher Ruth Van Vleet, very smartly and surely ahead of her time, made this a student-led process by leaving the entire design and construction of the crosswords to her students with a cash prize on offer to the member of her chemistry class that could produce the best example.24,25

In 1927, chemistry crosswords were mentioned as activities for instructors to consider using in extra-curricular Chemistry Clubs26 and following this, similar activities were published for the *Journal’s* readership to enjoy, including some that focused on particular chemistry-based themes such as chemical elements,27,28 amino acids,29 inorganic chemistry,30 metals,31 chemical symbols,32 non-metals,33 chemical history,34 and named reactions and apparatus.35 Despite a rich history of chemistry-based educational crosswords, literature evaluating their pedagogical benefit has only appeared in a handful of studies; with three being reported in the last ten years.14,36,37 These publications support the notion that crossword puzzles remain attractive teaching tools and this communication, as the latest such study, describes their effectiveness when used as online recreational tools for learning immediately prior to and during the COVID-19 pandemic.

Methodology

Crossword puzzles were created in portable document format (PDF) using crosswordhobbyist.com38 for students to complete as optional post-lecture revision aids, via their eBlackboard site. For each crossword, two versions were created, one without and one with answers; the latter typically being posted 5-7 days after the original crossword posting. In total, twelve crossword puzzles were created, six for first-year pharmacy students (*N*=132) to cover ten one-hour lectures and five two-hour problem class sessions on content relating to hybridization, nomenclature, functional group chemistry, chirality and isomerism, important drug properties, organic reaction mechanisms and carbonyl chemistry. The remaining six crosswords were constructed for second-year pharmacy students (*N*=120) based on ten one-hour lectures and four two-hour problem class sessions that covered topics such as the chemistry of benzene, heteroaromatic chemistry (Figure 1) and 1H and 13C NMR spectroscopy. Once posted, all crosswords remained visible across the entire academic year to enable students to revisit the content.



Figure 1. A crossword used as a second-year pharmacy student revision aid to supplement lecture and problem class content on heteroaromatic chemistry. This crossword was created through an online subscription with Crossword Hobbyist Inc. (crosswordhobbyist.com).

To assess the performance of the crossword puzzles, eBlackboard student tracking statistics, cohort exam scores and student feedback data were all fully scrutinized. All student data were treated confidentially and anonymously, and in line with the School’s ethics committee, no individual student data were shared or stored. In addition, a consistent academic standard was assumed between all student year groups due to strict enrollment requirements for the pharmacy course.

Student feedback was collected using an online questionnaire (*N*=93), which was separately emailed to both first and second-year students in the last week of the Spring semester. This consisted of five questions, the first three being closed quantitative questions and the remaining two being optional, open-ended qualitative questions. Students were informed that all responses would be treated anonymously and had 14 days to complete the questionnaire. Second-year student feedback was also achieved via team-based clicker handsets during a problem class in week 10 of the Autumn semester (*N*=28 teams). Using Turning Technologies NXT handsets with alphanumerical keypads and a multiple response function to allow all four team members to individually vote, students were able to answer 7-point Likert scale and free-text questions based on their experiences of using online crosswords. Similar clicker analysis was planned for first-year students however, this was curtailed due to the pandemic.

Results & Discussion

All results were collected at strategic intervals throughout the 2019-20 academic year to gauge whether student opinions and behaviors fluctuated during the teaching and assessment periods. This serendipitously enabled the comparison of data collected pre- and post-COVID-19 campus lockdown, with the latter period being in force across UK campuses for the final 9 weeks of the Spring semester.

Students’ Online Study Behavior Patterns

The total number of student online crossword viewings across the 2019-20 academic year was 17,717, which approximately equates to every student viewing each crossword three times, although clearly some students made a dozen or more views of each crossword while others chose not to view them at all. Of the total viewings, 7,471 (42%) were from year 1 (*N*=132) and 10,246 (58%) were from year 2 (*N*=120) students, with each year group showing a slight excess (between 5-16%) in favor of viewing crosswords that did not display the answers. This may support the notion that the majority of students conscientiously attempted the crosswords rather than focusing solely on the version containing the answers; a process that was successfully manipulated, in almost all cases, by the answers only being posted online 5-7 days after the initial crossword posting.

In all pre-COVID-19 data, the most popular day for viewing online crosswords was Wednesday and the least popular day was Saturday, while the most popular hour of study across the full 24-hour spectrum was 4-5pm. Since Wednesday afternoons are reserved in the academic calendar for sport and other recreational activities, it is clear that many students used this time, or subsequent time within that day, to engage with the online revision aids. This study pattern was consistently seen across all eBlackboard datasets and only varied when looking at data generated after the COVID-19 lockdown was in force.

During the lockdown period, the favored day and hour of study showed no general pattern, however, spikes in first-year views were consistent with the dates on which their online, open-book examinations took place; with these alternative assessments replacing the invigilated, closed-book examinations that would have normally occurred. This may point towards students using these crossword revision aids whilst being assessed in real-time or immediately before the assessments commenced. Unfortunately, more precise data are hard to unpick here as students were given a broad window within which they were able to start and finish the assessment, thus there was not a fixed start and finish time for all. Regardless of this, such findings suggest that students found these revision aids to be a resource worth accessing.

Aside from the online, open-book assessment days, students’ online viewing behavior appeared to lack a consistent structure during lockdown and as a consequence of this the author was keen to explore if study during the standard working hours of 9am to 5pm differed pre- and post-lockdown. Interestingly, there were no differences observed here, with a 50:50 split in terms of views occurring within and outside of standard working hours both pre- and post-lockdown.

Students’ Exam Performance

Pre-COVID-19 examination data (Table 1) collected for second-year students (*N*=120) showed that the online crosswords made no statistically significant differences to the 2019-20 mean and median cohort exam grades (*p*>.05) for the heteroaromatic chemistry question that had previously appeared in identical format on an exam paper sat by the 2017-18 cohort (*N*=96) in the absence of crosswords. In contrast, related studies have seen significant grade improvements, while one even reported both grade increases and decreases when crosswords were used on more than one class.11,14,37,39

Interestingly, as shown in Table 1, 27% more students opted to answer the heteroaromatic chemistry question from a choice of four when it was taught alongside online crossword exercises; suggesting the puzzles may have instilled greater confidence for that particular content, which was the same conclusion reached by both Crossman and Childers in similar studies involving psychology and sociology students, respectively.10,15 Furthermore, for this same question, 16.5% and 9.4% of students scored over 75% and 87.5%, respectively, when sitting the exam after crossword exposure, whereas only 7.1% and 0% of students scored over 75% and 87.5%, respectively, in the absence of the crosswords.

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| Table 1. Exam question performance with and without crossword revision aids | | | |
| Comparative data*a* | 2019-20 Cohort*b* with crossword puzzles | 2017-18 Cohortc without crossword puzzles |
| Number of student attempts | 85 (71%) | 42 (44%) |
| Mean grade out of 8 marks (SD) | 3.1 (2.3) | 2.6 (2.1) |
| Median grade out of 8 marks | 3.0 | 2.5 |
| Students scoring 6 out of 8 or higher | 16.5% | 7.1% |
| Students scoring 7 out of 8 or higher | 9.4% | 0% |
| *a*For a short-answer exam question requiring the insertion of missing starting materials, reagents and products for six heteroaromatic reactions (all content was covered by the crossword puzzle in Figure 1). This question featured on integrated second-year pharmacy exam papers alongside three other questions that assessed topics not covered by the crossword revision aids. For both cohorts this heteroaromatic chemistry question was used in identical fashion on the end of semester written exam and all students were instructed to only answer three questions from a choice of four for this section of the exam. *bN*=120 pharmacy students. *cN*=96 pharmacy students. SD = standard deviation. | | | |

The broader distribution of exam marks for the 2019-20 cohort (Table 1) is likely to reflect, to some degree, the level of student engagement with the crosswords, since these puzzles were the only obvious variable between the two cohorts (Table 1). Such reasoning is supported by Yuriev14 who reported a positive correlation between higher exam results and pharmacy students who attempted crosswords more than once. While it is important to be mindful that more engaged students will, by their very nature, typically be among the higher performers regardless of the revision tools at their disposal, it cannot be disputed that the crosswords positively impacted the exam performance for at least some individuals. Similar assessment evaluations were planned for first-year examinations, however, due to these taking place during the COVID-19 lockdown period such comparisons were deemed inequitable.

Anonymous Student Feedback

Online questionnaire data (*N*=93), obtained at the end of the COVID-19 lockdown period showed that 97.9% of second-year students attempted one or more crosswords, while for first-year students this figure was 78.3% (Figure 2). Furthermore, questionnaire data suggest that 46.8% of second-year students attempted all six crosswords whereas, only 8.7% of first-year students attempted this same number, highlighting very different levels of engagement. Clearly these data alongside the student viewing numbers highlight that some students, especially those in year 1, did not view any crosswords, while others viewed them multiple times.



Figure 2. The number of online crossword puzzles attempted by year 1 (*N*=46) and year 2 (*N*=47) students, based on an anonymous online student questionnaire. Each year group had six different crossword puzzles posted on their eBlackboard site as an additional revision aid to supplement lecture and problem class content.

Despite the second-year class being the smaller of the two year groups in this study (*N*=120 versus *N*=132), their number of crossword views was 2775 higher than for the first-year class. This may be explained by second-year crosswords having on average 17 clues per crossword, versus, an average of 26 clues for the first-year crosswords. Perhaps the reduced first-year engagement was as a direct consequence of their crosswords containing more content and being less palatable as quick recall aids, although four previous studies also reportedly used between 20 and 30 clues on each puzzle.14,20,40,41

Intriguingly, one of the crosswords posted for first-year students received 46% of their total number of viewings across all six crossword postings. This crossword covered a broader range of course content, which possibly made it a better revision tool compared with some, but interestingly, it also only consisted of 20 clues, which was the lowest number used for this cohort. A third variable here is the timing of the posting to meet the needs of the students. In reality the timing, type of subject matter and length of the crossword are all likely to influence the level of student participation.

Based on these cohort variations, it was not surprising to observe differing year group responses on a 7-point Likert scale when provided with statements relating to crosswords being both useful (Figure 3) and welcome in greater number as an online course resource (Figure 4). Second-year students were between 24.4% and 30.7% more agreeable on both counts, compared to their first-year counterparts. For this latter group, between 21.7% and 26.1% were neutral with regards to either statement (*cf*. 10.6% and 6.4% for second-year students), due to a comparable proportion of these first-year students (21.7%, Figure 2) not having attempted any of the crosswords and therefore not being in a position to have an opinion either way.



Figure 3. Student feedback responses by year 1 (*N*=46) and year 2 (*N*=47) students, when asked if online crossword puzzles were a useful revision aid. All data were collected by an anonymous online student questionnaire. 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral, 5 = somewhat agree, 6 = agree, and 7 = strongly agree.



Figure 4. Student feedback responses by year 1 (*N*=46) and year 2 (*N*=47) students, when asked if they would like more crossword puzzles embedded within their online learning environment. All data were collected by an anonymous online student questionnaire. 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral,   
5 = somewhat agree, 6 = agree, and 7 = strongly agree.

The overwhelmingly positive feedback obtained during COVID-19 lockdown from second-year students was reinforced by in-class clicker feedback data from the same group prior to lockdown where 80.9% (*N*=68) agreed to some extent that more crosswords should be embedded within their online learning environment (*cf*. 82.9% post-lockdown, *N*=47) while 8.8% disagreed to some extent (*cf.* 10.7% post-lockdown). Using the free-text response feature on clicker handsets during team-based problem classes, students were asked to describe online crossword exercises in one word, with the five most popular results being “helpful”, “great”, “fun”, “okay” and “useful”. These five descriptions accounted for a total of 17 team responses out of a total of 28 teams.

In similar fashion, the online post-COVID-19 lockdown questionnaire gave students an optional, open-text opportunity to comment on their experiences with online crossword puzzles and from combining results for both years 1 and 2 (*N*=20), responses such as, “fun”, “helpful”, “useful” and “enjoyable” were all received three or more times, along with comments such as “good tools” and “good knowledge testers”. Other comments described the crosswords as being “good for recall” and “great for kinesthetic learners” with one student also reporting how they were “constantly used during revision periods”. Feedback from one first-year student also described how the online crosswords “helped with some of the MCQs” that they answered as part of their COVID-19 reconfigured online, open-book examination.

As a consequence of the pandemic and while students were still fresh from their experiences of studying remotely, an optional, free-text question was inserted at the end of the online questionnaire to ask students to list the online revision aids that would best support them as distance learners. Due to similarities in responses seen from both first and second-year students these were merged and are summarized in figure 5 (*N*=48). Quizzes and puzzles (20.4%) came second only to instructional videos (46.3%) on students’ wish-list of online revision aids.



Figure 5. Combined year 1 and year 2 cohort feedback responses (*N*=48) to an optional open-text question asking students to state the online revision aids that would help them most when studying remotely. Only the top five revision aids were included, and these were the same for both cohorts. Data were calculated based on the number of references to each revision aid with some students listing more than one of these as part of their overall response.

For the purposes of figure 5, instructional videos, was a category heading used to cover student requests for lecture recordings, screencasts and videos providing explanations and additional information. The need for practice questions (14.8%) was the third most popular student response and in joint fourth place were eBooks and live discussions (9.3%), with the latter linked to requests for more face-to-face online conversations with both instructors and peers, as some students commented that they missed peer instruction and felt isolated and inadequately supported during the campus lockdown.

Future Plans During COVID-19 and Beyond

Due to global events some institutions have now committed to an online only form of delivery for the coming academic year. As such, the author has contemplated how these puzzles may further support instructors and students. In terms of the work presented here, one suggestion was to consider whether these puzzles should be delivered in a more interactive online format and therefore provide instant feedback, which was a request received on several student questionnaires. Many crossword building websites can certainly accommodate such a format, allowing answers to be directly entered into crossword cells on screen.14,38,42 However, it has been argued that the overlapping words, which clearly make a crossword what it is, by default, tend to show where mistakes have occurred. Crosswords therefore contain their own self-correction feature, as described by both Abuello12 and Shah,36 making the need for technology-driven feedback somewhat redundant.

For optimum student engagement and learning gains, instructors should focus on designing crosswords that help students identify the key themes and concepts within their course syllabus without embedding too many clues per puzzle or being too cryptic.42 If this indeed sounds like the instructor is generating the revision notes on the student’s behalf, then Ruth Van Vleet’s student-led activity, whereby the students created their own crosswords,24 might actually be the preferable active learning model to apply here. This approach has already been utilized by Corticone,18 however, in keeping with the results of this communication, no appreciable differences in exam performance were noted following its inclusion, but student feedback was extremely positive.

Both Childers15 and more recently Corticone18 have suggested how students could work collaboratively to create crosswords before engaging in a puzzle-sharing swap. To date, most crossword projects have instead explored a cooperative learning model where students work in groups of 2-3 or 6-7 to solve, rather than to create crosswords during teaching sessions.20,40,41,43 With the current COVID-19 restrictions in place, arranging students into small online groups, tasked with constructing, sharing and solving puzzles appears a plausible and attractive model that builds on previous literature accounts while helping to re-establish the peer instruction that some students believe they have lost since the lockdown of university campuses.

Concluding remarks

The evaluation of online crossword puzzle viewings by students prior to and during the COVID-19 pandemic, has illustrated how lockdown led to some behavioral changes to students’ online study patterns. Student feedback has also brought into clear focus the online teaching resources that students would like should campus lockdowns continue. As students continue to adapt in the coming academic year to their studies alongside the strict social distancing rules and the new normal caused by the COVID-19 pandemic, all educators must prepare themselves for the reality that face-to-face delivery may be limited solely to an online platform, making remote active learning resources and other online course content of greater importance than ever before.

This communication demonstrates that educators can nimbly build-up their online learning resources using traditional, no-frills puzzles that can engage learners with quick recall exercises that auto-assess course knowledge. Efficiently reconfiguring course content in a helpful manner that the majority of students support and seamlessly respond to, without creating an added financial burden on schools or departments, is crucial for a sector grappling with the many uncertainties that have been produced by the COVID-19 pandemic. Fun, low-cost, crossword revision aids can be easily constructed while helping to remotely support and engage students at a time when many have become unexpected distance learners.

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