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# An Evaluation of Secondary School Students' Use and Understanding of Learning Strategies to Study and Revise for Science Examinations

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**Abstract:** There is currently no population-based data evaluating secondary school-aged students' use, or understanding of, learning strategies to study/revise independently for science. There is also no research evaluating the effort students make towards independent science study and revision, nor how schools support students with study and/or revision strategies for science examinations. In this paper, we report data from a representative sample of 385 students (aged 14 to 15 years) from 29 secondary schools in the UK, using the Effective Revision and Study Strategies Questionnaire (ERaSSQ) survey. We conducted a cross-sectional survey using a multistage implicitly stratified sampling method. Our results show that the learning strategies most frequently used by students for independent science study and revision were making notes, repeatedly reading information, and highlighting or underlining information (i.e., lower utility learning strategies). Our findings also suggest many students do not have a complete understanding of the strategies that are known to have higher utility (i.e., retrieval and spaced practice). These results represent the first attempt to gather information using robust survey methods and are of interest to secondary school science teachers and education policymakers.

**Keywords:** evaluation; effective learning strategies; secondary school students; independent study and revision for science learning

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## 1. Introduction

Improving educational outcomes using evidence-informed approaches is a key goal of education systems and has been the focus of attention for researchers and policymakers over recent years (Gorard et al., 2020; Slavin, 2020; White, 2019). Examples include the Australian Education Research Organisation (AERO) and the Education Endowment Foundation in the UK, who have produced guidance for schools and created repositories of evidence and research outputs, and the development of the National Strategy for Educational Research and Enquiry (NSERE) in Wales has aimed to align education policy and practice to more evidence-informed approaches (Welsh Government, 2021). However, despite the growing acceptance of the importance of using evidence in practice, recent research suggests that the uptake of evidence and research by teachers and school leaders remains limited (Education Endowment Foundation, 2021; Gorard et al., 2020; Pegram et al., 2022, 2024).

One important area of teaching that can benefit from evidence-informed approaches is the advice and support provided to learners to help them with the metacognitive and selfregulation strategies, including independent study and revision (Astbury, 2022; Dunlosky et al., 2013; Dunlosky, 2013; Hogh & Müller-Hilke, 2021). However, there is a dearth of robust evidence to guide policy and practice in this area. In this paper, we aim to improve the understanding of this important aspect of learner behaviour by evaluating what strategies school-aged learners' currently use, including their understanding of more evidence-informed, higher utility strategies.

This study forms part of a suite of studies undertaken as part of a collaborative approach to school improvement between the North Wales Regional School Improvement Service (GwE) and the Collaborative Institute for Education Research, Evidence and Impact (CIEREI), Bangor University. This collaborative approach is based on a memorandum of understanding designed to help schools make use of evidence-informed approaches to improve outcomes for learners (Nisar et al., 2023; Owen et al., 2022; Tyler et al., 2019; Watkins et al., 2022). The current study was commissioned as an evaluation to help GwE understand how well learners in schools in north Wales make use of higher utility approaches to study and revise and to assess to what extent schools promote these more promising strategies. These findings would be used to enhance GwE school improvement support and improve the quality of provision in schools.

### 1.1. Background

Science forms a key part of the curriculum in school systems across the world. In the UK, science has been a compulsory subject in the school curriculum since 1989, and the effective teaching of science is vital for prosperity, economic growth, as well as for the public understanding of contemporary issues such as climate change. The Organisation for Economic Co-operation and Development (OECD, 2014b, 2017, 2020) has highlighted that a solid grounding in school science is an important prerequisite to enable students to engage with many of the challenging issues facing contemporary society. Over recent years, the United Nations Educational, Scientific and Cultural Organization (UNESCO) has created a framework for the promotion of science and education to help address the climate change crisis (UNESCO, 2020, 2022).

In the most recent PISA assessments in 2022, fifteen education systems performed above the OECD average in science (485 points), and about three out of four students achieved basic proficiency in science in OECD countries (OECD, 2023). In Wales, the standards learners achieve in science as well as the uptake of science subjects by students for further education has been an area of concern and debate for some time (Wightwick, 2017a, 2017b), and findings from the previous rounds of PISA tests have shown that the average science score for 15 year old secondary students in Wales has not compared favourably with the OECD average, nor with other parts of the UK (OECD, 2010, 2014a; Sizmur et al., 2019; Jerrim, 2021). Students' science scores in Wales remained lower than the OECD average when Wales first participated in PISA in 2006 and have remained below the other nations of the UK in the most recent PISA rankings in 2018 and 2022 (Ingram et al., 2023; OECD, 2007; Wightwick, 2019). Additional thematic inspection reports in Wales have also highlighted the need to improve the standards students achieve in secondary schools (Estyn, 2017).

Using effective learning strategies in schools is an essential factor to help improve outcomes for students. Research indicates that approaches such as retrieval and spaced practice are likely to be more effective in helping students achieve learning goals and can play an important role in the acquisition of core subject knowledge and in preparation for external science examinations (Adesope et al., 2017; Agarwal et al., 2021; Dunlosky et al., 2013; Karpicke & Aue, 2015; Roediger & Karpicke, 2006; Sotola & Crede, 2020).

Despite the growing evidence supporting effective learning strategies, there remains a paucity of empirical research surrounding secondary school students' use of learning strategies for independent study and/or revision. Prior research has focused on the use of learning strategies, but there are currently no studies that have evaluated secondary school students' understanding of the utility of these strategies or how schools support students to use more promising approaches (Agarwal et al., 2014; Dirkx et al., 2019). There is also very little research that has reported on the effort students make towards independent study and revision (i.e., time spent studying and revising) (Agarwal et al., 2014; Oakes & Griffin, 2016). Additionally, the generalisability of much published research on students' study practice is hampered by the use of non-probability sampling methodologies (i.e., convenience sampling), making it difficult to extrapolate findings.

### *1.2. Learning Strategies*

Oakes and Griffin (2016) describe learning strategies as the activities students undertake for their independent work or how they go about learning key content and ideas on their own outside of the classroom without help from teachers. Examples of commonly used learning strategies include repeated reading approaches (i.e., repeatedly reading a core subject textbook or class book in order to understand and recall the content), completing retrieval practice activities (such as quizzes or attempting to answer previous exam papers), and making notes (e.g., key note taking, summarising texts) (Dirkx et al., 2019; Karpicke et al., 2009).

Over recent years, there have been significant contributions to the research literature on learning strategies (Coe et al., 2014; Education Endowment Foundation, 2021; Gorard & See, 2016; Jones, 2022; Moran & Malott, 2004; Rosenshine, 2012; Weinstein et al., 2018), several books and resources (Agarwal et al., 2020; Carey, 2015; Carpenter & Agarwal, 2020; Horvath et al., 2016), and a growing number of web-based and smartphone programmes (e.g., Quizlet [https://quizlet.com/en-gb accessed on 31 July 2024], Kahoot [https://kahoot.com/ accessed on 31 July 2024], and Quizziz [https://quizizz.com/ accessed on 31 July 2024]). Several studies have indicated that using higher utility learning strategies is related to improved outcomes in examinations, whereas the use of lower utility strategies is related to poorer outcomes (Bartoszewski & Gurung, 2015; Gurung et al., 2010; Hartwig & Dunlosky, 2011; Rodriquez et al., 2018).

In an important monograph summarising the evidence on learning techniques, Dunlosky et al. (2013) evaluated ten commonly used learning strategies and arranged these into low, medium, and high utility categories based on how effective the strategies generalise across a range of key variables (e.g., learning conditions, student characteristics, materials, and criterion tasks). Of these ten learning strategies, two strategies were identified as high utility (practice testing [note that we use the term retrieval practice in this study to include all activities involving the recall of information from memory] and distributed practice [note that we use the term spaced practice in this study]), three strategies were identified as having moderate utility (interleaved practice, elaborative interrogation, and self-explanation), and five strategies were identified as having lower utility (summarising, highlighting [or underlining], using keyword mnemonics, imagery use for text learning, and repeatedly reading information). In this study, we focused on the evaluation of six of the learning strategies described by Dunlosky et al. (2013), as well as three other commonly used learning strategies identified in the literature on students' study practice, from our pilot study, and via knowledge gained from school leaders (Blasiman et al., 2017; Debbag et al., 2021; Garwood et al., 2018; Hartwig & Dunlosky, 2011; Morehead et al., 2016; Safar et al., 2014; Oakes & Griffin, 2016; Ying et al., 2017).

### 1.3. Evidence on the Use and Understanding of Learning Strategies

A review of the current literature yielded only two studies reporting findings on the use of learning strategies in secondary school settings and one study reporting findings in primary school settings (Agarwal et al., 2014; Dirkx et al., 2019; Yin et al., 2024). Previous studies are limited to surveys of undergraduate students, mainly in the social sciences, medicine, pharmacy, and dentistry (Almoslamani, 2022; Bartoszewski & Gurung, 2015; Biwer et al., 2020b; Blasiman et al., 2017; Gurung et al., 2010; Hartwig & Dunlosky, 2011; Hogh & Müller-Hilke, 2021; Karpicke et al., 2009; Kornell & Bjork, 2007; McAndrew et al., 2015, 2016; Peña et al., 2021; Piza, 2018; Rovers et al., 2018; Rodriquez et al., 2018; Schmidmaier et al., 2011; Susser & McCabe, 2013; Morehead et al., 2016). These studies have consistently shown that undergraduate students predominantly use lower utility learning strategies for independent study, such as repeated reading approaches and highlighting information during study, rather than using higher utility strategies such as retrieval and/or spaced practice.

Agarwal et al.'s (2014) study of secondary school students showed that these learners also relied on lower utility strategies such as repeated reading, as opposed to higher utility approaches such as retrieval practice. However, it is worth noting that Agarwal et al.'s (2014) findings are based upon data collected from students at the end of an experimental study on learning strategies, and this may have influenced students' responses. A study by Dirkx et al. (2019) found that Dutch school students similarly relied on lower utility learning strategies, including repeated reading approaches and making notes. Their study revealed that just over half of those that responded ranked repeated reading of information as their primary learning strategy (51.1%), and, in contrast, a very low proportion ranked retrieval practice as their primary learning strategy (8.1%). However, Dirkx et al. (2019) did not report students' understanding of various learning strategies.

More recently, a study by Yin et al. (2024) explored the correlation between the use of learning strategies and academic performance from a sample of primary school age students in China. Their study revealed inconsistent findings between the impact of learning strategies and academic outcomes. The use of more promising approaches was not consistently linked to improved outcomes. However, Yin et al.'s (2024) findings are based on a narrow age range of learners attending primary schools in a very different education setting compared to those of previous studies.

Barriers to the optimal use of evidence-informed learning strategies by students for independent work include factors related to student understanding of learning strategies, effort toward independent work, and recommendations from educators (Biwer et al., 2020a; Blasiman et al., 2017; Hartwig & Dunlosky, 2011; Kornell & Bjork, 2007; McCabe, 2011; Morehead et al., 2016; Peña et al., 2021; Susser & McCabe, 2013).

Studies in university settings have shown that undergraduate students have limited knowledge of higher utility learning strategies, and they primarily use retrieval practice as a diagnostic tool to evaluate their learning, rather than as a method to actually learn information (Hartwig & Dunlosky, 2011; Kornell & Bjork, 2007; Kornell & Son, 2009; McAndrew et al., 2016; McCabe, 2011; Morehead et al., 2016; Piza, 2018; Schmidmaier et al., 2011). Blasiman et al. (2017) asked university students to rate the effectiveness of various learning strategies and found that lower utility learning strategies were rated as effective by the highest proportion of students (i.e., reading and highlighting notes). To date, there has not been any comparable research undertaken with secondary school students.

There is also a lack of published research describing the effort secondary school-aged students make towards independent study and/or revision in schools (Agarwal et al., 2014). In recent studies on the use of more promising approaches in university settings, students reported that allocating additional time and effort became a barrier to the use of higher utility strategies (Biwer et al., 2020a; Peña et al., 2021). Despite the importance of investing time and effort to maximise the impact of using higher utility learning strategies, there remains a paucity of evidence on the effort secondary school-aged students make towards independent study and revision (Oakes & Griffin, 2016).

School teachers are an important source of information and guidance for students as they prepare to learn and revise for examinations. Studies have shown that university instructors frequently promote both lower and higher utility learning strategies and have a moderate understanding of evidence-informed learning strategies (McCabe, 2018; Piza, 2018; Morehead et al., 2016). Previous published research on instructors' recommendations and understanding of learning strategies is limited to surveys of higher education instructors, and there remains a paucity of research evaluating the strategies teachers most commonly promote in schools (see Surma et al. (2022) for an exception; McCabe, 2018; Piza, 2018; Morehead et al., 2016).

Previous research has often failed to ask learners about their use of learning strategies for a specific subject or exam (see Agarwal et al. (2014) for an exception, although these findings are based on data collected from students at the end of an experimental study on retrieval practice). Therefore, one of the aims of this study was to measure students' study practices as they work towards the General Certificate in Secondary Education (GCSE) science award in the UK. In Wales, students begin studying towards the General Certificate in Secondary Education (GCSE) in Year 10 (age 14–15 years). Students follow a 2-year programme of study for each GCSE subject, and there are four compulsory subjects for all learners (English, Welsh, mathematics, and science). Learner progress is assessed through a combination of examinations, coursework, and teacher assessment. Importantly, the GCSE qualifications students achieve play a significant role in determining their future academic and career paths and are highly valued by schools, colleges, universities, and employers. In this study we focused on the learning strategies used by secondary school students (aged 14 to 15 years) as that was a key evaluation priority for GwE.

Although the current study focused on students in Wales, schools in other nations across the UK follow very similar GCSE curricula and organisational structure. Therefore, the results from this study are likely to be generalisable to learners of this age across the UK and possibly to other, similar, countries across the world. Research into students' study practice that focuses exclusively on the UK education system is limited, so gathering reliable information on the strategies students use to study can provide important information to help schools improve the quality of the advice they provide. This information will also be invaluable for school improvement professionals and providers of teachers' initial education.

### *1.4. Study Design*

Previous research on learning strategies for study and revision has predominantly used non-probability sampling methods (i.e., convenience sampling). A limitation of this approach is that the results are likely to be biassed towards the over- or under-reporting of students who were more or less interested and, therefore, more or less likely to volunteer to take part in the survey based on their interest. Psychological research is frequently based on convenience samples of undergraduate students, and a recent study showed that findings from studies exploring literacy and numeracy skills based on convenience samples of undergraduate students were not representative of the general population nor of age-matched nonstudents (Wild et al., 2022). In this study, we used a random probability sampling method (i.e., multistage implicitly stratified sampling) to obtain a random sample of school learners. As we included a stratified random sample of students following different science qualifications, our results are less likely to be distorted due to the potential under-representation of students who were less academically able and were following a science qualification that made up a smaller proportion of the student population.

*1.5. Study Goal, Objective, and Research Questions*

Our aim in the current study was to evaluate the study practice of secondary school students aged 14–15 for GCSE science examinations. The research questions for this study were as follows: (1) Which learning strategies do students use to study and/or revise in preparation for science examinations? (2) What are students' understanding of some commonly used learning strategies? (3) How much time do secondary school students invest to study and revise independently to prepare for science examinations? (4) Which learning strategies do school teachers encourage students to use for science study/revision, and how do schools support students to use these strategies?

## 2. Method

A cross-sectional survey using a multistage implicitly stratified sampling method was chosen for this study. The target population for the current survey was defined as school students aged between 14 and 15 years studying external GCSE science qualifications in mainstream secondary schools in north Wales, United Kingdom. We calculated a sample size of 924 school students aged between 14 and 15 years following statistical guidelines in the Sampling and Sample Size Calculation guide produced by the National Institute for Health Research (NIHR) Research Design Service (Fox et al., 2007), as well as advice from a survey statistician. We planned our sample size on a student population of 6900, with a desired precision of 0.03, and using the most conservative assumed element variance with a 95% confidence interval. We conducted a cross-sectional survey using a multistage implicitly stratified sampling method between April 2019 and July 2019 using paper-based questionnaires. At the first stage of the sampling process, we invited all 54 mainstream maintained secondary schools in the 6 local authorities in north Wales (Anglesey, Gwynedd, Conwy, Denbighshire, Flintshire, and Wrexham) to participate in the survey. This ensured all schools in the region, irrespective of size, language category, and geographical location, were invited to participate. Twenty-nine schools agreed to take part.

The inclusion criteria for school students were (1) students aged between 14 and 15 years (school Year 10) and (2) students studying either the triple GCSE science award, double GCSE science award, and BTEC and/or applied science awards. The first author randomly selected a sample of students proportionate to the total number of students in the Year 10 cohort from an anonymised list of students provided by each school. To ensure that the sample of students represented different ability levels, we used an anonymised list of Year 10 students sorted according to the science qualification they were studying (e.g., all students studying triple GCSE science were listed first, followed by all students studying double GCSE science and then all students studying BTEC and/or applied GCSE science). The science qualification information was then used as an indicator of students' academic ability in school science (i.e., more academically able students typically follow the triple science award, with the remaining students generally following the double science and BTEC and/or applied science qualifications). Every *n*th student was then selected on the list (after a random starting point was generated). This allowed every eligible school student an equal chance of selection and allowed representation of each ability level in the final sample for each school in its correct proportion.

Study information and consent letters were forwarded to the parents and carers. This informed parents and carers about their child's participation in the study and provided the option to withdraw them from the survey. We obtained ethical approval for this study from the Research Ethics Committee of Bangor University (ethical approval number: 2018–16316).

### 2.1. Survey Procedure

We developed the Effective Revision and Study Strategies Questionnaire (ERaSSQ) survey using the Jisc Online Surveys programme (https://www.onlinesurveys.ac.uk/ accessed on 1 October 2018). All students completed the ERaSSQ in school under the supervision of the first author (or an independent data collector) and a member of the school staff.

We provided participants both a verbal and written introduction to the research study and survey. We emphasised that students' answers would be treated with confidentiality, that there were no 'right' or 'wrong' answers, and that their responses would not reflect on their current science performance or their school. The students were then given the opportunity to consider their participation in the survey, opt-out, or provide assent prior to completing the questionnaire. The printed questionnaires were completed by students on their own in a quiet room (one student received assistance from a learning support teaching assistant). The survey could be completed in English or Welsh. Completion of the survey questionnaire was self-paced, and the session took approximately 30 min. Students were thanked for their assistance and given a debrief about the study. Neither students nor schools were remunerated for their participation in the survey.

### 2.2. Survey Measure Development

We developed the ERaSSQ survey to assess the study habits of secondary school students for independent study and revision in preparation for GCSE science examinations. The focus was on independent study and revision, including learning on their own, usually outside of the classroom setting. The design of the ERaSSQ survey was informed by earlier studies on students' study practice, including key aspects of students' study and revision practice (Blasiman et al., 2017; Dunlosky et al., 2013; Kornell & Bjork, 2007; Oakes & Griffin, 2016). These included the use and understanding of learning strategies, school-based support for study/revision, and students' effort towards independent learning (i.e., study and revision). The learning strategies evaluated by ERaSSQ included six of the learning strategies described by Dunlosky et al. (2013), as well as three additional learning strategies gathered from a review of the literature, our pilot study, and information from school leaders. Existing instruments for assessing students' use of learning strategies, such as the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991), do not include the learning strategies evaluated by Dunlosky et al. (2013) or questions on students' understanding of learning strategies.

### 2.3. Reliability Testing and Pilot Study

We could not calculate Cronbach's alpha scores for the ERaSSQ as it measures individual strategies on a Likert scale rather than using grouped items to measure a single construct. The survey items are unrelated and are not intended to collectively represent a broader construct.

We piloted the ERaSSQ on a convenience sample of 535 students (aged 14 to 17 years) attending five secondary schools in north Wales between June 2018 and July 2018. To assess the student understanding of the ERaSSQ survey, we also asked students to complete respondent debrief forms immediately after completing the ERaSSQ survey. The debrief forms included open-ended questions to measure students' comprehension of the survey questions and learning strategies. In the questions in the debrief forms, we asked students to paraphrase the survey questions. Overall, students communicated that they understood the content of the survey questions, and their feedback was used to improve the clarity of the language for less able readers. Revised versions of the English and Welsh surveys were proofread by an experienced senior science examiner.

### 2.4. Effective Revision and Study Strategies Questionnaire

#### 2.4.1. Use and Understanding of Learning Strategies

To measure students' use of learning strategies, we asked students to rate how often they used nine common learning strategies on a 5-point Likert scale from never (1) to always (5) (see item 1). The nine learning strategies are presented in Table 1. The students also had the option to list a learning strategy(ies) that was not mentioned in the list (see item 2). We then asked the students to write down the three learning strategies they most frequently used from the nine listed strategies and rate how helpful the three learning strategies are on a 5-point Likert scale from not at all helpful (1) to extremely helpful (5) (see item 3). In the current evaluation, for the survey, we did not give students any prior information on Dunlosky et al.'s (2013) utility ratings of the learning strategies.

**Table 1.** Overview of commonly used learning strategies evaluated in the ERaSSQ questionnaire [1].

| Learning Strategy | | Description | Strategy Utility |
|---|---|---|---|
| **Terms Used in the ERaSSQ Questionnaire** | **Terms Used by Dunlosky et al. (2013)** | | |
| Using mind maps [2] | | Writing down a key topic, and from this, creating links composed of keywords, phrases, concepts, facts, and figures. Mind maps are typically presented as diagrams. | |
| Highlighting or underlining information | Highlighting/underlining | Marking, underlining important information. | Low |
| Using flashcards [3] | | Writing key terms, facts or to be learned information on small cards. Flashcards are typically two-sided with the prompt/question appearing on one side and the information about the prompt/answer on the other. | |
| Repeatedly reading information | Rereading | Reading information over and over. | Low |
| Making notes (summarising) | Summarisation | Writing notes/summaries (of various lengths. | Low |
| Spaced practice | Distributed practice | Spreading study/revision sessions over time. | High |
| Doing practice tests * | Practice testing | (i.e., retrieval practice) Retrieving information from memory by completing practice tests (e.g., past papers). | High |
| Interleaved practice | Interleaved practice | Mixing study of different, related topics, concepts, or problems. | Moderate |
| Elaborate encoding [4] | | Connecting what you are trying to learn to what you already know (e.g., using mnemonics). Making connections between information to be learned and other information. | |

[1] The ERaSSQ assessed the use of six learning strategies evaluated by Dunlosky et al. (2013) and categorised into low, moderate, and higher utility strategies. Using information gathered from a review of the literature, our pilot study, and information from school leaders, three additional learning strategies were also included (using flashcards, using mind maps and elaborate encoding). [2,3,4] Neither of these strategies were recognised in the review by Dunlosky et al. (2013). [3] Using flashcards and doing practice tests can be used as retrieval practice activities. However, in the present study, we analysed using flashcards and doing practice tests separately. * In the ERaSSQ survey, we used the term 'doing practice tests' to refer to retrieval practice with students. The table consists of six learning strategies from Dunlosky et al.'s (2013) monograph.

To measure students' use of learning strategies for the three different science subjects (biology, chemistry, and physics), we asked students if they used any of the nine listed strategies to study/revise for these three subjects (see item 6). To measure students' understanding of the benefits of retrieval practice, spaced practice, using flashcards, and mind maps as learning strategies, we asked students to choose one option that indicated why they would use each strategy to prepare for an upcoming science exam (adapted from Kornell & Bjork, 2007) (see items 9 to 12).

#### 2.4.2. School Based Support for Study/Revision

To measure which learning strategies teachers most commonly promote in schools, we asked students if their current science teacher(s) had encouraged them to use any of the nine learning strategies to study/revise for science (see item 4). The students also had the option to list a learning strategy(ies) that was not mentioned in the list (see item 5). To evaluate whether there is a need to provide additional information and support on the use of evidence-informed learning strategies in secondary schools, we also asked whether schools offer students assistance with study/revision skills for science and if they were interested in learning about evidence-informed learning strategies to help them study and/or revise (see items 14 to 16).

#### 2.4.3. Students' Effort Towards Independent Learning (i.e., Study and Revision)

To measure effort towards independent study, we asked students how many hours of study they engage in for science outside of science lessons in a typical week (see item 7). To measure effort towards revision, we asked students how many hours of revision they complete in the weeks leading up to a science exam (see item 8). These questions were informed by Oakes and Griffin (2016).

### *2.5. Statistical Analysis*

Although this survey design included equal selection probabilities, not all sampled units (i.e., schools and students) were observed. To attempt to more appropriately represent all 14 to 15 year old students studying in mainstream maintained secondary schools in north Wales, we made several weighting adjustments to compensate for survey non-response, coverage errors, and aligning the population proportions. The final weighting variable in this dataset is a multiplication of: (1) school design weight; (2) school non-response weight; (3) student design weight; and, (4) and post-stratification weights.

The school design weight is 1 for all schools given the take-all design. To calculate the school non-response weight, we conducted a logistic regression analysis model to estimate the probability of school response based on variables known for responding and non-responding schools. These include the following: (1) the 2018/19 national school categorisation system for Wales was used as a proxy for school effectiveness (Welsh Government, 2020); (2) the percentage of students in Year 10 eligible for free school meals (eFSM) for 2018/19; (2) school GCSE science attainment scores for Year 10 in 2018/19; and, (4) the school attendance of students in Year 10 for 2018/19. The logistic regression model results (i.e., propensity scores for responding and non-responding schools) are presented in Table 2. These school data were provided by GwE. The school weight is the inverse of the estimated probability values (i.e., 1 divided by the estimated response probability for each school).

**Table 2.** Estimated response probability values for participating and non-participating secondary schools.

| School | Participation | Value | % |
|---|---|---|---|
| 1 | Responding | 0.72759189 | 72.7 |
| 2 | Responding | 0.65277217 | 65.2 |
| 3 | Responding | 0.3642495 | 36.4 |
| 4 | Responding | 0.7602036 | 76 |
| 5 | Responding | 0.84309707 | 84.3 |
| 6 | Responding | 0.42637519 | 42.6 |
| 7 | Responding | 0.47931596 | 47.9 |

**Table 2.** *Cont.*

| School | Participation | Value | % |
|---|---|---|---|
| 8 | Responding | 0.75307349 | 75.3 |
| 9 | Responding | 0.5310775 | 53.1 |
| 10 | Responding | 0.70797791 | 70.7 |
| 11 | Responding | 0.65135538 | 65.1 |
| 12 | Responding | 0.61724712 | 61.7 |
| 13 | Responding | 0.70259986 | 70.2 |
| 14 | Responding | 0.85185089 | 85.1 |
| 15 | Responding | 0.48992396 | 48.9 |
| 16 | Responding | 0.56952291 | 56.9 |
| 17 | Responding | 0.54139134 | 54.1 |
| 18 | Responding | 0.61857378 | 61.8 |
| 19 | Responding | 1.105661404 | 90.4 |
| 20 | Responding | 3.345490287 | 29.8 |
| 21 | Responding | 3.706861813 | 26.9 |
| 22 | Responding | 1.448201091 | 69 |
| 23 | Responding | 1.507444954 | 66.3 |
| 24 | Responding | 1.318875712 | 75.8 |
| 25 | Responding | 2.276885642 | 43.9 |
| 26 | Responding | 1.597278799 | 62.6 |
| 27 | Responding | 1.102764154 | 90.6 |
| 28 | Responding | 1.626240734 | 61.4 |
| 29 | Responding | 1.743823777 | 57.3 |
| 30 | Non-responding | 0.33580105 | 33.5 |
| 31 | Non-responding | 0.79934106 | 79.9 |
| 32 | Non-responding | 0.79948971 | 79.9 |
| 33 | Non-responding | 0.685584411 | 68.5 |
| 34 | Non-responding | 0.5539197 | 55.3 |
| 35 | Non-responding | 0.46898431 | 46.8 |
| 36 | Non-responding | 0.39665792 | 39.6 |
| 37 | Non-responding | 0.41371147 | 41.3 |
| 38 | Non-responding | 0.59187677 | 59.1 |
| 39 | Non-responding | 0.37902727 | 37.9 |
| 40 | Non-responding | 0.47580188 | 47.5 |
| 41 | Non-responding | 0.19048599 | 19 |
| 42 | Non-responding | 0.52871052 | 52.8 |
| 43 | Non-responding | 0.19160134 | 19.1 |
| 44 | Non-responding | 0.56285587 | 56.2 |
| 45 | Non-responding | 0.0102443 | 1.02 |
| 46 | Non-responding | 0.42745028 | 42.7 |
| 47 | Non-responding | 0.09527013 | 9.5 |
| 48 | Non-responding | 0.59617691 | 59.6 |
| 49 | Non-responding | 0.41784843 | 41.7 |
| 50 | Non-responding | 0.46108937 | 46.1 |
| 51 | Non-responding | 0.63695908 | 63.6 |
| 52 | Non-responding | 0.05520233 | 5.5 |
| 53 | Non-responding | 0.10503136 | 10.5 |
| 54 | Non-responding | 0.78675497 | 78.6 |

The survey design we employed ensured equal student selection probabilities are equivalent to the ratio of the number sampled within a school (ni) to the population size of the school (Ni). The design is such that the sample selected is proportionate to the school size and hence equal across all students within school. In this instance, for all students, $ni/Ni \cong 0.134$, and the design weight for all students is the inverse of this number. We weighted student data to use post-stratification techniques, as the number of variables to build a non-response model was limited to only one (science award), which was available for responding and non-responding students. For post-stratification, our aim was to weight the observed data (i.e., from respondents) to known totals of the population. There were two variables available: student gender and science award. The population data on student science awards were obtained from the sample frame, and the data on student gender were obtained from the Welsh Government Pupil Level Annual School Census (PLASC) data for 2019 (Statistics for Wales, 2019). However, there were missing data for some respondents for gender (5.7%). To use the post-stratification techniques, we first imputed gender on these missing cases using hot-deck methods (Andridge & Little, 2010). Missing cases were replaced by values of similar cases within the science award categories based on responses to survey items four through six. We then used iterative proportional fitting (IPF) to estimate the post-stratification weights to these two marginal proportions (Kolenikov, 2014). The final survey weight is then a multiplication of the several weighting adjustments, which compensated for the survey design, unit non-response, and aligning population proportions.

The item response rate for each survey item in the present study was greater than 95.0% and, therefore, no further steps were taken to assess potential item non-response bias (Pazzaglia et al., 2016). Any missing data were handled using pairwise deletion. The development of the survey weights was performed using the statistical software functions in R and STATA (version 15). Due to the complex sample design (i.e., multistage), we analysed the data using SPSS Complex Samples (version 25), which incorporates the weighting variable as well as the survey design into survey analysis. In addition, we also used the 'survey' package in R for analysing data from complex surveys to analyse survey item three.

### 2.6. Analysis of Open-Ended Responses

In addition to the nine learning strategies listed in the ERaSSQ survey, we gave students the opportunity to report any additional learning strategy(ies) they used. The first author evaluated all responses to the open-ended questions and constructed separate categories for responses that were not one of the nine learning strategies listed in the survey. Although some of the students' responses were considered to be examples of the nine listed strategies (e.g., making notes, retrieval practice), we constructed separate categories for all the open-ended responses, as this provided valuable information on how students adapt strategies and on students' understanding of learning strategies. The new categories were: (1) making notes; (2) using learning resources; (3) using learning resources to complete retrieval practice activities; (4) watching and/or listening to learning resources; (5) completing other retrieval practice activities; (6) teaching and/or studying with others; and, (7) undertaking other activities (i.e., one of the nine listed learning strategies that was used differently). The second author then undertook an independent review of the responses and categories. Agreement was assessed and any discrepancies were discussed. The first author then classified all the open-ended responses into the seven categories.

## 3. Results

### 3.1. Response Rates

Twenty-nine secondary schools in north Wales, United Kingdom, participated in the survey. This represents a response rate of 53.7%. The response from selected students in participating schools was 74.8%, generating 385 completed questionnaires. Table 3 presents the characteristics of the participating schools, and Table 4 presents the characteristics of the participating students.

**Table 3.** Characteristics of the participating secondary schools.

| | Variable | Participating Schools |
| --- | --- | --- |
| | | *n* |
| Location (i.e., local authority) | Anglesey | 4 |
| | Gwynedd | 9 |
| | Conwy | 2 |
| | Denbighshire | 3 |
| | Flintshire | 7 |
| | Wrexham | 4 |
| Language category of school | Bilingual (Type A) | 7 |
| | Bilingual (Type B) | 3 |
| | English medium | 12 |
| | English with significant Welsh | 2 |
| | Welsh medium | 4 |
| School size | Small [1] | 14 |
| | Medium-sized [2] | 9 |
| | Large [3] | 6 |
| School eFSM percentage [4] | Up to 8 per cent | 8 |
| | Over 8 per cent and up to 16 per cent | 15 |
| | Over 16 per cent and up to 24 per cent | 5 |
| | Over 24 per cent and up to 32 per cent | 1 |
| | Over 32 per cent | |

[1] Small refers to secondary schools with 600 students or fewer. [2] Medium-sized refers to schools with between 601, and 1100 students. [3] Large refers to schools with 1101 or more students. Definitions of school sizes were adopted from the Estyn report on school size and educational effectiveness (Estyn, 2013). eFSM represents students eligible for free school meals. [4] School eFSM percentage refers to the mean percentage from the last three years.

**Table 4.** Characteristics of the participating secondary students.

| | Variable | Participating Students | % |
| --- | --- | --- | --- |
| | | *n* | |
| Gender | Male | 199 | 50.9 |
| | Female | 167 | 43.4 |
| | Other | 4 | 1.0 |
| | Prefer not to say | 13 | 3.4 |
| GCSE/BTEC science award | GCSE triple science | 75 | 19.5 |
| | GCSE double science | 299 | 77.7 |
| | BTEC and/or GCSE applied science | 11 | 2.9 |
| Location (i.e., local authority) | Anglesey | 51 | 13.2 |
| | Gwynedd | 80 | 20.8 |
| | Conwy | 36 | 9.4 |
| | Denbighshire | 49 | 12.7 |
| | Flintshire | 106 | 27.5 |
| | Wrexham | 63 | 16.4 |

### *3.2. What Learning Strategies Do Secondary School Students Most Commonly Use for Science?*

The primary aim of this survey was to evaluate which learning strategies secondary school students use to study and/or revise to prepare for their science examinations, including six of the learning strategies described by Dunlosky et al. (2013) (Table 1). We asked students to indicate how often they used the nine common learning strategies to study/revise for science. Table 5 shows the nine learning strategies, and the median weighted scores are ranked from highest to lowest by their reported average frequency of use (with higher values indicating higher frequency of use). The percentages of students reporting the various frequencies per learning strategy are presented in Table 6. The results indicated that the less effective learning strategies were most frequently used by secondary students for science examinations, including making notes, repeatedly reading information, highlighting, or underlining information. Retrieval practice (doing practice tests) and spaced practice (i.e., more effective strategies) were less commonly used by students.

**Table 5.** Weighted median (IQR *) scores for student responses to the survey question "How often do you use the following learning strategies when you study/revise for science?" (Survey Item 1).

| Learning Strategy | m * (IQR) | SE |
|---|---|---|
| Making notes (summarising) | 3.5 (2) | 0.1 |
| Repeatedly reading information | 3.5 (2) | 0.1 |
| Highlighting or underlining information | 3.5 (2) | 0.1 |
| Doing practice tests [1] | 2.7 (2) | 0.1 |
| Spaced practice | 2.6 (2) | 0.1 |
| Using mind maps | 2.4 (1) | 0.1 |
| Using flashcards | 2.1 (2) | 0.1 |
| Elaborate encoding | 1.7 (2) | 0.0 |
| Interleaved practice | 1.3 (1) | 0.0 |

Learning strategies are arranged from most to least often used, based on median scores. Students' ratings of how often they used the nine learning strategies were made on a 5-point Likert scale, from never (1) to always (5). Higher ratings indicate higher frequency of use. [1] In the ERaSSQ survey, we used the term 'doing practice tests' to refer to retrieval practice with students. * m refers to the median of the student sample. For the current study, we surveyed a sample of students and not the entire population of interest (i.e., target population); therefore, we used the statistical notation m to refer to the sample median.

**Table 6.** Weighted percentage scores for student responses to the survey question "How often do you use the following learning strategies when you study/revise for science?" (Survey Item 1).

| Learning Strategy | Never | Rarely | Sometimes | Most of the Time | Always |
|---|---|---|---|---|---|
| | % [CI] | % [CI] | % [CI] | % [CI] | % [CI] |
| Using mind maps | 12.9 [9.0, 18.1] | 23.1 [19.3, 27.4] | 39.8 [34.7, 45.2] | 18.8 [14.3, 24.3] | 5.3 [3.2, 8.7] |
| Highlighting or underlining information | 5.7 [3.7, 8.7] | 11.9 [8.7, 15.9] | 24.8 [20.7, 29.4] | 39.1 [33.3, 45.2] | 18.5 [13.8, 24.5] |
| Using flashcards | 21.6 [16.3, 28.0] | 26.8 [22.0, 32.2] | 24.6 [20.7, 29.0] | 15.2 [11.6, 19.7] | 11.9 [8.0, 17.3] |
| Repeatedly reading information | 5.1 [3.6, 7.3] | 12.0 [8.5, 16.7] | 17.1 [13.5, 21.4] | 33.9 [28.3, 40.1] | 31.8 [26.5, 37.7] |
| Making notes (summarising) | 3.9 [1.9, 7.9] | 8.4 [6.1, 11.3] | 19.4 [15.4, 24.2] | 37.9 [32.2, 43.9] | 30.4 [25.4, 35.9] |
| Spaced practice | 12.1 [8.7, 16.4] | 21.1 [17.6, 25.1] | 29.7 [25.2, 34.6] | 22.4 [18.5, 26.7] | 14.8 [11.3, 19.2] |
| Doing practice tests [1] | 7.9 [5.3, 11.7] | 20.9 [16.0, 26.8] | 31.0 [26.1, 36.4] | 22.7 [17.3, 29.0] | 17.5 [13.1, 23.0] |
| Interleaved practice | 40.6 [35.9, 45.5] | 30.3 [25.7, 35.3] | 21.6 [17.1, 27.0] | 5.6 [3.6, 8.6] | 1.9 [0.9, 3.9] |
| Elaborate encoding | 31.8 [25.9, 38.3] | 25.7 [20.4, 31.8] | 28.5 [24.0, 33.4] | 10.6 [7.1, 15.6] | 3.4 [2.0, 5.9] |

[1] In the ERaSSQ survey we used the term 'doing practice tests' to refer to retrieval practice with students.

The qualitative data from the free response question about students' use of additional learning strategy(ies) were classified into seven broad categories, and the percentage of students with a response in each category was computed. Two of the responses could not be categorised. Some students mentioned more than one additional learning strategy, which fitted into multiple other categories. The categories were: (1) making notes; (2) using learning resources; (3) using learning resources to complete retrieval practice activities; (4) watching and/or listening to learning resources; (5) completing other retrieval practice activities; (6) teaching and/or studying with others; and, (7) undertaking other activities. A description of the seven categories, as well as examples from each category, alongside respondent's characteristics are presented in Table 7.

**Table 7.** Students' reports of use of additional learning strategies (Survey Item 2).

| Category | Description | % (*n*) | Example |
|---|---|---|---|
| Making notes | Making notes using posters, Post-it notes, diagrams, mind maps, and/or using other note-taking approaches. | 23.8 (34) | "Watch and make notes on videos from GCSEPod" (General Certificate of Secondary Education) (female participant, following GCSE triple science award). "I make revision posters and put them up in my bedroom so I see them often" (female participant, following GCSE double science award). "Vibrant notes across the walls of my room" (female participant, following GCSE double science award). |
| Using learning resources | Using web-based and/or smartphone learning resources (e.g., Bitesize [1], GCSEPod [2] WJEC [3] (Welsh Joint Education committee), Tanio.cymru [4] Isaac Physics [5]) or hard copy learning resources (such as revision guides) without specifying how these learning resources were used to learn the content. | 18.2 (26) | "Website e.g., Bitesize, Tanio.cymru (female participant, following GCSE triple science award). Using Bitesize" (female participant, following GCSE triple science award). "Go online on (Tanio.cymru) and learn from that" (male participant, following GCSE double science award). |
| Using learning resources to complete retrieval practice activities | Using web-based and/or smartphone learning resources to complete retrieval practice activities (e.g., completing tests/quizzes on Bitesize [1], WJEC [3], Quizziz [6], Tanio.cymru [4], Kahoot [7]). | 7.7 (11) | "Use online tests like WJEC" (male participant, following GCSE triple science award). "Take quizzes online or on science revision apps" (female participant, following GCSE double science award). "Online quizzes, Bitesize" (female participant, following GCSE triple science award). |
| Watching and/or listening to learning resources | Watching and/or listening to learning resources (e.g., on YouTube [8], GCSEPod [2], Bitesize [1], Tanio.cymru [4] website, or content developed by students). | 18.9 (27) | "Watch science videos on YouTube" (female participant, following GCSE triple science award). "Watch science revision on Twig/YouTube" (male participant, following GCSE double science award). "Online videos and online presentations from Tanio. Cymru" (male participant, following GCSE double science award). "Making songs and voice notes and repeatedly listen to it" (female participant, following GCSE double science award). |
| Completing other retrieval practice activities | Completing other retrieval practice activities (i.e., any activity involving recall of information from memory). For example, being tested by others, completing quizzes, completing cloze text activities, and writing their own questions. | 15.4 (22) | "My friend goes through every topic asking a variety of questions that he makes on the spot. Once he reached the end of topics. I then go through the same process with him. This usually takes 2 h" (male participant, following GCSE triple science award). "Getting a family member to test me" (female participant, following GCSE triple science award). "By having my friends ask me questions" (female participant, following GCSE double science award). "Short quick fired questions" (female participant, following GCSE double science award). |
| Teaching and/or studying with others | Teaching others and/or studying with others (e.g., friends, family, study groups). | 4.2 (6) | "Dysgy y gwybodaeth i person arall/teaching the information to another person" (male participant, following GCSE triple science award). "Gael rhywyn ddarllen allan i mi/have someone else read out to me" (male participant, following GCSE double science award). "Explaining/telling other people about the work" (female participant, following GCSE triple science award). |

**Table 7.** *Cont.*

| Category | Description | % (*n*) | Example |
|---|---|---|---|
| Undertaking other activities | Using one of the common learning strategies assessed in this study differently (i.e., highlighting and/or underlining information or notes, reading information or notes, spaced practice, elaborate encoding). | 11.9 (17) | "Reading revision books" (male participant, following GCSE double science award). "Aroleuno pethau pwysig/highlighting important things" (female participant, following GCSE double science). |

[1] Bitesize [https://www.bbc.co.uk/bitesize accessed on 1 June 2024], [2] GCSE Pod [https://www.gcsepod.com/ on 1 June 2024], [3] WJEC [https://www.wjec.co.uk/ accessed on 1 June 2024], [4] Tanio Cymru [http://tanio.cymru/ accessed on 1 June 2024], [5] Isaac Physics [https://isaacphysics.org/ accessed on 1 June 2024], [6] Quizziz [https://quizizz.com/ accessed on 31 July 2024], [7] Kahoot [https://kahoot.com/ accessed on 31 July 2024], [8] YouTube [https://www.youtube.com/ accessed on 1 June 2024].

### 3.3. Students' Ratings of the Effectiveness of the Most Frequently Used Learning Strategies

We also aimed to evaluate students' beliefs on the effectiveness of the learning strategies based on the categorisation described by Dunlosky et al. (2013) (Table 1). Table 8 shows the nine learning strategies, the weighted percentages of students who reported using the learning strategies (arranged from most to least frequently used), and students' ratings of the perceived efficacy of the learning strategies they most often used (higher values indicating higher perceived efficacy). The results indicated that the learning strategies students ranked as more effective were lower utility strategies, such as making notes, repeatedly reading information, and highlighting or underlining information (Table 8).

**Table 8.** Weighted percentage scores for students' use of the common learning strategies, and the weighted median (IQR *) scores for students' ratings of how helpful they are (Survey Item 3).

| Learning Strategy | % | m * (IQR) | SE |
|---|---|---|---|
| Making notes (summarising) | 20.6 | 3.5 (1) | 0.1 |
| Repeatedly reading information | 16.0 | 3.4 (1) | 0.1 |
| Highlighting or underlining information | 14.9 | 3.3 (1) | 0.1 |
| Using mind maps | 14.6 | 3.2 (1) | 0.1 |
| Doing practice tests [1] | 14.0 | 3.5 (1) | 0.1 |
| Using flashcards | 12.2 | 3.5 (1) | 0.1 |
| Spaced practice | 3.8 | 3.3 (2) | 0.3 |
| Elaborate encoding | 2.3 | 3.5 (1) | 0.6 |
| Interleaved practice | 1.7 | 2.4 (2) | 0.4 |

Proportions are based on the three learning strategies students reported most frequently using. Student ratings of how effective they believed the three strategies they most commonly used were made on a 5-point scale, from not at all helpful (1) to extremely helpful (5). Higher ratings indicate that the students rated the strategy as more effective. [1] In the present study, we used term 'doing practice tests' to refer to retrieval practice in the ERaSSQ survey. * The statistical notation m refers to the median of the student sample. For the current study, we surveyed a sample of students and not the entire population of interest (i.e., target population); therefore, we used the statistical notation m to refer to the sample median.

### 3.4. Which Learning Strategies Are Students Encouraged to Use by Secondary School Teachers?

The secondary aim of this survey was to identify how schools support students with study/revision for science, including an evaluation of the learning strategies secondary school teachers encourage students to use (Table 1). To measure which learning strategies they are encouraged to use, we asked the students whether their current science teacher(s) had encouraged them to use any of the nine common learning strategies. Figure 1 shows the weighted percentages of students reporting whether they were encouraged to use any of the nine learning strategies. The results indicated that teachers promote both higher and lower utility strategies.

The qualitative data from the free response question about any additional learning strategy(ies) the students reported being encouraged to use by their current science teachers were also classified into seven broad categories. The new categories were: (1) to use learning resources; (2) to use learning resources to complete retrieval practice activities; (3) to watch and/or listen to learning resources; (4) to use other retrieval practice activities; (5) to make notes; (6) to teach and/or study with others; and, (7) to use other activities (i.e., one of the nine listed learning strategies that was used differently). A description of the seven categories, as well as examples from each category, alongside respondent's characteristics are presented below in Table 9.

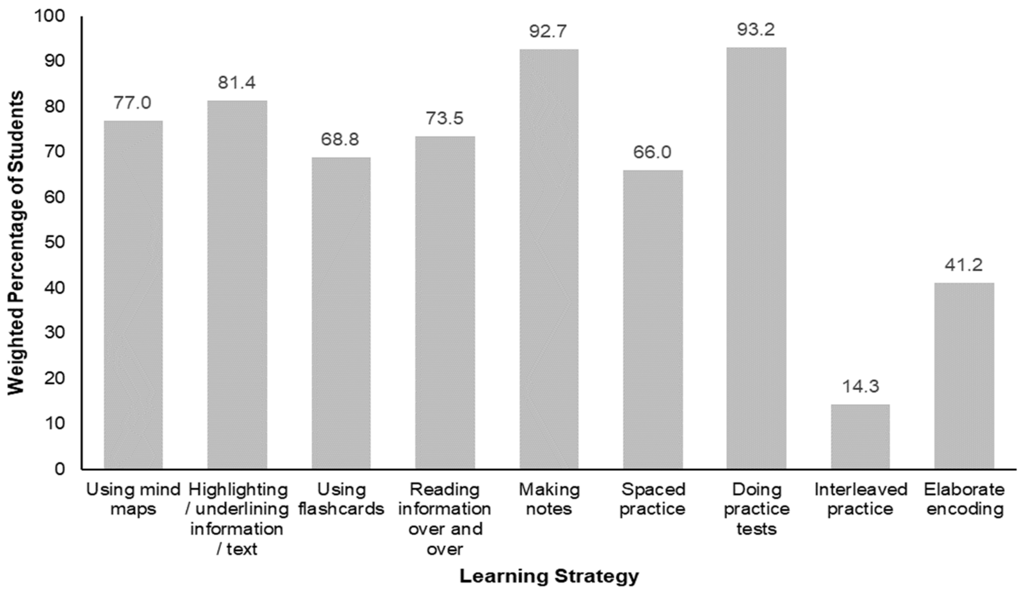


**Figure 1.** Weighted percentage scores for student responses to the survey question "Have any of your current science teacher(s) encouraged you to use any of the following learning strategies when you study/revise for science?" (Survey Item 4).

**Table 9.** Students' reports on use of additional learning strategies as encouraged by their school teacher(s) (Survey Item 5).

| Category | Description | % (*n*) | Example |
|---|---|---|---|
| To use learning resources | To use web-based and/or smartphone learning resources (e.g., Bitesize [1], GCSEPod [2], WJEC [3], Tanio.cymru [4], Isaac physics [5]) or physical learning resources (such a revision guides), without specifying how their teacher might have encouraged students to use these learning resources to learn the scientific content. | 33.3 (25) | "GCSEPod/Tanio.cymru website" (male, following GCSE triple science award). "Online resources e.g., GCSEPod" (female participant, following GCSE double science award). "Defnyddio y we, Tanio.cymru/Use the Tanio.cymru website" (female participant, following double GCSE science award). "Use a revision website called Tanio.cymru to revise for science" (female participant, following GCSE double science award). "Usually encouraged to use websites such as Bitesize" (male, following GCSE double science award). |
| To use learning resources to complete retrieval practice activities | To use web-based and/or smartphone learning resources to complete retrieval practice activities (e.g., completing tests/quizzes on Bitesize [1], Quizziz [6], Tanio.cymru [4], Kahoot [7], or answering past papers questions using WJEC). | 13.3 (10) | "Using a good website which tests you" (female participant, following GCSE double science award). "Take quizzes on science revision apps" (female participant, following GCSE double science award). "Use revision guides, answer test questions" (female participant, following GCSE double science award). |
| To watch and/or listen to learning resources | To watch and/or listen to learning resources (e.g., on [8] YouTube, GCSEPod, Bitesize, Tanio.cymru website). | 13.3 (10) | "Watch video clips online from Cbac (WJEC) and Bitesize websites" (male participant, following GCSE double science award). "The use of GCSEPod, Tanio.cymru, watching videos about the subject" (female participant, following GCSE triple science award). "Defnyddio clipiau fidio, Tanio.cymru/Use video clips, Tanio.cymru" (female participant, following GCSE double science award). |

**Table 9.** *Cont.*

| Category | Description | % (*n*) | Example |
|---|---|---|---|
| To use other retrieval practice activities | To complete other retrieval practice activities (i.e., any activity involving recall of information from memory). For example, being tested by others, completing quizzes, completing cloze text activities, and writing their own questions. | 17.3 (13) | "Question and answer. Give your parents some questions to ask and answer" (male participant, following GCSE triple science award).<br>"Making questions, doing quick questions and answering them" (female participant, following GCSE double science award).<br>"Recalling all the information we know on a topic and writing it on to a piece of paper and then going through our notes to check its right" (female participant, following GCSE double science award).<br>"Recall strategy, write down what you know in two minutes and then check to see if it's right" (female participant, following GCSE double science award). |
| To make notes | To make notes using posters, Post-it notes, diagrams, mind maps, and/or using other note-taking approaches. | 10.7 (8) | "Using diagrams and labelling them" (male participant, following GCSE double science award).<br>"Encouraged to make bright and colourful posters" (participant preferred not to say gender, following GCSE double science award).<br>"Draw a huge circle and add sectors and in the sectors write information of each topic" (female participant, following GCSE double science award).<br>"Revision posters, Post-it notes" (female participant, following GCSE double science award). |
| To teach and/or study with others | To teach others and/or study with others (e.g., friends, family, study/revision sessions, or groups) to learn and/or revise science knowledge. | 4.0 (3) | "Revising by helping another to understand a subject" (male participant, following GCSE triple science award).<br>"Revision sessions in school" (female participant, following GCSE double science award).<br>"Drop in session. Hot seat" (female participant, studying GSCE double science award). |
| To use other activities | To use one of the common learning strategies assessed in this study differently (i.e., highlighting and/or underlining information or notes, reading information or notes, spaced practice, elaborate encoding). | 8.0 (6) | "Reading the information out loud" (female participant, following GCSE double science award).<br>"Uwcholeou geiriau pwysig/highlighting important words" (female participant, following GCSE double science award).<br>"Looking through your books" (female participant, following GCSE double award). |

[1] Bitesize [https://www.bbc.co.uk/bitesize accessed on 1 June 2024], [2] GCSE Pod [https://www.gcsepod.com/ accessed on 1 June 2024], [3] WJEC [https://www.wjec.co.uk/ accessed on 1 June 2024], [4] Tanio Cymru [http://tanio.cymru/ accessed on 1 June 2024], [5] Isaac Physics [https://isaacphysics.org/ accessed on 1 June 2024], [6] Quizziz [https://quizizz.com/ accessed on 31 July 2024], [7] Kahoot [https://kahoot.com/ accessed on 31 July 2024], [8] YouTube [https://www.youtube.com/ accessed on 1 June 2024].

### *3.5. Which Learning Strategies Do Students Use for the Three Science Subjects (i.e., Biology, Chemistry and Physics)?*

To measure which learning strategies students use to study/revise for each of the three science subjects (biology, chemistry, and physics) on their own outside of science lessons, we asked students to indicate using a 'yes' or 'no' response option against each strategy. Table 10 shows the nine learning strategies, and the weighted percentages of students who reported using the learning strategies for each science subject.

**Table 10.** Weighted percentage scores for student responses to the survey question "Which of the following learning strategies do you use to study/revise for the three science subjects?" (Survey Item 6).

| Learning Strategy | Biology | Chemistry | Physics | Biology and Chemistry | Biology, Chemistry and Physics | Chemistry and Physics | Biology and Physics | None of the Sciences |
|---|---|---|---|---|---|---|---|---|
| | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) |
| Using mind maps | 14.9 (1.8) | 5.5 (1.7) | 5.8 (1.5) | 6.7 (1.4) | 36.0 (3.3) | 1.5 (0.6) | 7.3 (1.7) | 22.2 (2.7) |
| Highlighting or underlining information | 7.7 (1.3) | 5.7 (1.2) | 4.1 (1.0) | 7.6 (1.7) | 54.8 (3.0) | 5.6 (1.3) | 3.1 (1.0) | 11.4 (2.1) |
| Using flashcards | 11.0 (1.7) | 7.5 (1.7) | 6.4 (1.2) | 5.4 (1.3) | 32.0 (4.3) | 2.3 (0.9) | 3.7 (0.9) | 31.8 (3.5) |
| Repeatedly reading information | 6.8 (1.3) | 4.9 (1.1) | 4.1 (1.0) | 4.7 (1.5) | 63.3 (3.0) | 4.2 (1.1) | 3.4 (1.1) | 8.6 (1.3) |

**Table 10.** *Cont.*

| Learning Strategy | Biology | Chemistry | Physics | Biology and Chemistry | Biology, Chemistry and Physics | Chemistry and Physics | Biology and Physics | None of the Sciences |
|---|---|---|---|---|---|---|---|---|
| | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) | % (SE) |
| Making notes (summarising) | 4.0 (0.9) | 5.1 (1.1) | 5.8 (1.2) | 4.2 (1.3) | 66.8 (2.6) | 3.0 (0.8) | 4.0 (1.0) | 7.2 (1.4) |
| Spaced practice | 6.6 (1.3) | 7.6 (1.7) | 5.6 (1.1) | 5.1 (1.6) | 37.7 (2.5) | 4.3 (1.0) | 2.8 (1.0) | 30.4 (2.3) |
| Doing practice tests [1] | 5.6 (1.6) | 5.8 (1.6) | 4.3 (0.9) | 4.8 (1.0) | 61.7 (3.4) | 5.2 (1.0) | 4.2 (1.1) | 8.4 (1.8) |
| Interleaved practice | 4.2 (1.2) | 5.3 (1.4) | 2.8 (0.8) | 5.6 (1.3) | 13.3 (1.6) | 4.1 (0.9) | 1.8 (0.6) | 63.0 (2.5) |
| Elaborate encoding | 11.7 (2.5) | 7.4 (1.5) | 12.0 (1.7) | 3.7 (1.7) | 12.0 (1.9) | 2.7 (0.9) | 5.8 (2.1) | 44.7 (3.8) |

[1] In the present study, we used the term 'doing practice tests' to refer to retrieval practice in the ERaSSQ survey.

### 3.6. How Much Effort Do Students Invest to Study and Revise on Their Own (i.e., Time Spent Studying and Revising)?

In this survey, we also aimed to identify how much effort (i.e., time) do secondary students invest to study and revise in preparation for science examinations. To measure how much time secondary students invest to study and revise for science on their own outside of science lessons, we asked students to indicate how much time they spent studying in a typical week for science outside of lessons. Next, we asked students to indicate how much time they spent revising in the weeks leading up to a science exam. Figure 2 shows the weighted percentages of students reporting the various number of hours of study and the number of hours of revision. The results indicated that students reported spending more time revising in the weeks leading up to a science test (3 to 4 h) than they spent studying in a typical week (less than 1 h). These results show that students appear to distribute their independent study and revision time unevenly for science examinations.

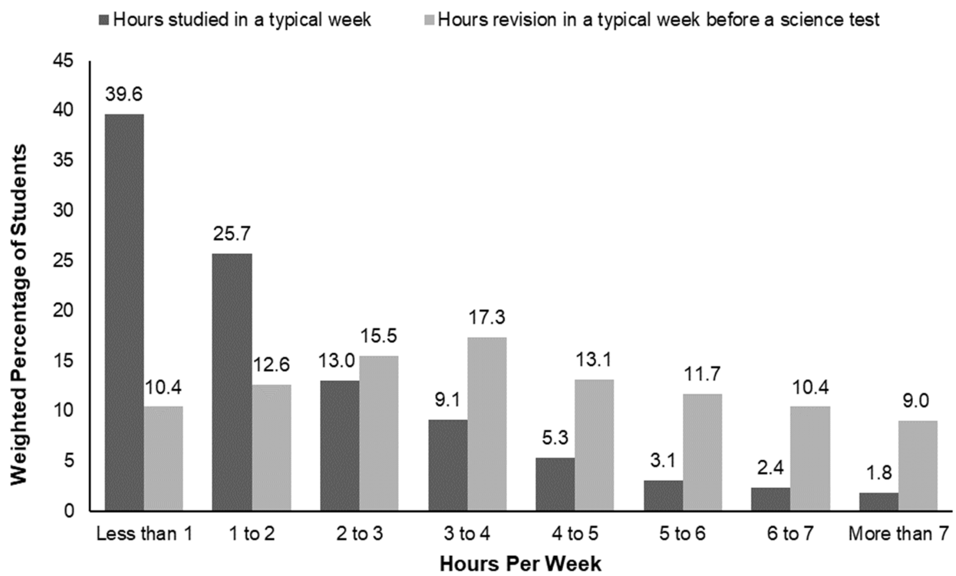


**Figure 2.** Weighted percentage scores for student responses to the survey questions "In a typical week how many hours of study do you do for science outside of lessons" and "In the weeks leading up to a science test how many hours do you revise in preparation outside of lessons?" (Survey Items 7 and 8).

### 3.7. Students' Understanding of the Benefit of Retrieval Practice (Doing Practice Tests), Spaced Practice, Flashcards, and Mind Maps

In this survey, we also aimed to evaluate students' understanding of how helpful some learning strategies are for learning science. Table 11 shows the weighted percentages of students' understanding of the benefits of retrieval practice (doing practice tests), spaced practice, using mind maps, and using flashcards. The results indicated that students are not maximising on the potential of more effective strategies (i.e., retrieval practice) to help them study/revise for science. Importantly, secondary students are not cognisant of the benefits of using higher utility learning strategies, such as retrieval practice as an effective approach that can be used with a range of materials and learning conditions (i.e., flashcards, past papers). Our results showed that over half (53.3%) of students reported that they identify retrieval practice as a strategy to help them assess their learning (i.e., to identify what they know and/or do not know) rather than as an effective learning strategy in itself.

**Table 11.** Weighted percentage scores for understanding of the benefits for using retrieval practice (doing practice tests), spaced practice, flashcards, and mind maps (Survey Items 9 to 12).

| Learning Strategy | Response Option | % [CI] |
|---|---|---|
| Doing practice tests [1] (e.g., past papers) | Doing practice tests when I study/revise will help me to know how well I have learnt the information for the science test. | 53.3 [47.1, 59.5] |
| | Doing practice tests when I study/revise will help me to learn and remember the information for the science test. | 33.8 [28.4, 39.6] |
| | I do not think doing practice tests when I study/revise will help me to learn and remember the information for the science test. | 12.9 [9.6, 17.1] |
| Spaced practice | Spacing out my study/revision sessions over multiple days/weeks will help me to learn more information for the science test. | 27.6 [22.0, 34.0] |
| | Spacing out my study/revision sessions over multiple days/weeks will help me to learn and remember the information for the science test. | 58.5 [52.1, 64.6] |
| | I do not think spacing out my study/revision sessions over multiple days/weeks will help me learn and remember the information for the science test. | 14.0 [10.4, 18.6] |
| Flashcards | Using flashcards when I study/revise will help me to learn because it allows me to read the information over and over. | 15.9 [12.3, 20.4] |
| | Using flashcards when I study/revise will help me to learn because it allows me to practise bringing the answer to my mind. | 32.1 [25.2, 39.9] |
| | Using flashcards when I study/revise will me to learn because it helps break up the information into smaller amounts to practise. | 32.1 [28.0, 36.4] |
| | I do not think using flashcards when I study/revise will help me learn the information for the science test. | 19.9 [15.1, 25.8] |
| Mind maps | Using mind maps when I study/revise will help me to learn because it allows me to read the information over and over. | 20.4 [17.3, 24.0] |
| | Using mind maps when I study/revise will help me to learn because it allows me to practise bringing the information to my mind. | 21.9 [16.4, 28.8] |
| | Using mind maps when I study/revise will help me to identify the main topic and link this to related topics, with words that make sense to me. | 41.1 [34.9, 47.5] |
| | I do not think using mind maps when I study/revise will help me learn the information for the science test. | 16.6 [12.8, 21.2] |

[1] In the present study, we used the term 'doing practice tests' to refer to retrieval practice in the ERaSSQ survey.

### *3.8. Do Secondary Schools Currently Provide Students with Support for Science Study/Revision? Is There a Demand for Information About Evidence-Informed Learning Strategies to Study/Revise for Science?*

To further evaluate whether there is a need to provide additional information and support on the use of evidence-informed learning strategies in secondary schools, we asked whether schools offer students assistance with study/revision skills for science. Table 12 shows the weighted percentages of students reporting whether schools offer advice on study/revision skills to support students with independent work. Finally, we asked students if they were interested in learning about evidence-informed learning strategies to help them study/revise more effectively for science. Table 12 shows the weighted percentages of students reporting whether students should be provided with information about effective learning strategies and if they were interested in receiving this information.

The results indicated that students would like to receive more information about effective learning strategies to help them study and/or revise for science.

**Table 12.** Weighted percentage scores for student responses to the survey questions about availability and demand for support with study/revision (Survey Items 14 to 16).

| Survey Item | Response Option | % | SE |
|---|---|---|---|
| Does your school offer all pupils in Year 10 study/revision skills support to help you study/revise for science? | Yes | 76.5 | 3.8 |
| | No | 8.3 | 2.2 |
| | I don't know | 15.2 | 2 |
| Do you think that you should be provided with information about effective learning strategies to help you study/revise for science? | Yes | 96.1 | 1.3 |
| | No | 3.9 | 1.3 |
| Would you be interested in receiving information about evidence-based learning strategies that will help you to study/revise effectively for science? | Yes | 81.7 | 2.5 |
| | No | 18.3 | 2.5 |

## 4. Discussion

We report the results of the first regional survey to evaluate the use and understanding of learning strategies by secondary school students (aged 14 to 15 years) in mainstream schools in the UK to study and/or revise for science examinations. In addition, we report the effort that students' make towards independent study and revision for science and the advice they receive from schools. As this study utilised a more representative methodology, the findings are likely to generalise more broadly to students in other regions of the UK, where students follow very similar science qualifications in comparable school settings. In the following section, each of these aspects of students' study practice are discussed.

### *4.1. Use of Learning Strategies*

Our results showed that the learning strategies assigned a lower utility ranking by Dunlosky et al. (2013) were most frequently used by learners, including making notes, repeatedly reading information, highlighting, or underlining information. Retrieval practice (doing practice tests) and spaced practice (i.e., higher utility strategies) were less commonly used, and these findings align closely with the outcomes of previous studies which found that secondary-aged students relied on lower utility learning strategies (Agarwal et al., 2014; Dirkx et al., 2019). Oakes and Griffin (2016) also found that students studying advanced level academic courses in the UK (aged 16–17 years) similarly relied on low utility learning strategies (i.e., reading approaches and highlighting information) as opposed to higher utility strategies such as retrieval practice, suggesting that the results in this study might be generalisable to the wider secondary school population. Importantly, the findings from this study, based on a robust sampling methodology, confirm that secondary learners do not prioritise the use of higher utility learning strategies.

Students also reported using highlighting or underlining information more frequently than using retrieval practice. In contrast, Dirkx et al. (2019) reported that students more frequently reported using retrieval practice activities, followed by highlighting/underlining information. Dirkx et al. (2019) suggested that the nature of the question format in such surveys (e.g., open-format with students reporting the strategies, or closed-format with respondents selecting strategies from a predefined list) might influence student reports of strategy use. The present study included nine common learning strategies and presented these in a list whilst providing students the opportunity to report any additional strategies they use. By providing students with a list of learning strategies, our aim was to ensure students did not overlook any common learning strategies they use. This study also used a response scale based on how often each strategy was used, giving students the choice to select a response option from never to always for how frequently, if at all, students used each strategy. This approach is more likely to provide a valid indicator of strategy use.

Other factors that could have contributed to the difference between Dirkx et al. (2019) and the present study may be related to the study design (i.e., sampling methodology) and/or cultural differences between students in the Netherlands and the United Kingdom. The present study used a stratified random sampling method to ensure the sample represented different student ability groups, whereas the Dirkx et al. (2019) study did not specify the sampling methodology that was employed in the three participating Dutch secondary schools.

### *4.2. How Do Students' Understandings of Learning Strategies Relate to Their Use of Learning Strategies?*

The present study has shown that learners do not generally have an accurate understanding of the effectiveness of the learning strategies they most frequently use. Importantly, the learning strategies students rated as being more effective are identified as lower utility strategies by Dunlosky et al. (2013), including making notes, repeatedly reading information, and highlighting or underlining information. This indicates that students are not benefitting from more effective strategies due to either inaccurate and/or incomplete understandings of the relative utility of these approaches. This finding has important implications for developing learning programmes to improve the study habits of students as well as providing useful information for both schools, school improvement professionals, and also providers of teacher initial education.

We also found that over half (53.3%) of the students reported that they identify retrieval practice (doing practice tests) as a strategy to help them assess their learning (i.e., to identify what they know and/or do not know) rather than as an effective learning strategy in itself. This finding suggests that most students were not aware of the advantage of using retrieval practice (doing practice tests) as a learning strategy when studying and/or revising for science. One possible reason for this could be students' everyday experience of completing retrieval practice activities for formative and/or summative purposes in school (e.g., end of unit tests).

Most of the students (58.5%) reported that spacing practice would have helped them to learn and remember information when studying and/or revising for science, suggesting that most students understand that spacing is beneficial for learning. However, in this study, spaced practice was the fifth most commonly used learning strategy students reported using. Findings from a study by Susser and McCabe (2013) indicate that university students were aware of the spacing advantage, although these older learners similarly reported using this strategy less frequently compared to more suboptimal strategies, such as repeated reading. The inconsistency between learners' understanding and utilisation of spaced learning may be partly to do with a lack of knowledge about the learning advantage of spaced practice (i.e., the spacing effect), which can help to slow down the rate of forgetting newly learned information (Bahrick et al., 1993; Ebbinghaus, 1885/2006). Another tentative explanation is that spacing is a strategy based on *when* learners should practise instead of *how* to practise and, therefore, students might not have considered spaced practice as a learning strategy when completing the survey.

### *4.3. Effort Towards Independent Study and Revision*

This study also evaluated the effort students make towards independent work (i.e., time spent studying and revising) and the advice they receive from school teachers. Our findings show that students reported spending more time revising in the weeks leading up to a science test (3 to 4 h) than spent studying in a typical week (less than 1 h). These findings are in line with results from Agarwal et al. (2014), who also reported students spending more time studying and revising when there was an upcoming test compared to in a typical week when there were no exams. As students appear to distribute their independent study and revision time unevenly, they are unlikely to be able to use spaced practice as an effective strategy (which is based on implementing a regular schedule of study practice that spreads activities over time). The present study highlights the need to inform students about distributing their independent study and revision efforts more evenly over time to successfully incorporate effective learning strategies.

### *4.4. Support with Study and Revision Strategies*

Most students in this study (92.7%) reported that their science teacher(s) encouraged them to use retrieval practice (doing practice tests). However, when interpreting these promising results, it is important to consider that we have previously noted that most of the students reported that they would complete retrieval practice (doing practice tests) to assess their learning rather than as a learning strategy. This finding suggests that although schools are promoting retrieval practice, students are not using this strategy to its maximum potential. One reason students might not be using retrieval practice as a learning strategy could be due to their everyday classroom experience of teachers using tests for summative and/or formative purposes. Also, students reported that their science teacher(s) encouraged the use of lower utility strategies such as making notes, repeatedly reading information, and highlighting or underlining information. Although our findings suggest that there is an important role for teachers to promote retrieval practice (doing practice tests) as an effective learning strategy, further research now needs to focus on teachers' understanding of retrieval practice and other high utility strategies and how best to communicate this information to learners.

### *4.5. Use of Additional Learning Strategies*

This study allowed students to report any additional learning strategies they use for independent study and revision. Interestingly, student responses to the open-ended questions included examples of how students had modified the use of some of the nine predefined learning strategies included in this study (e.g., making notes, retrieval practice). A possible explanation for this might be that although students encounter general descriptions of how each strategy can help them learn, in the absence of more detailed and practical guidance, they are likely to adapt some of these strategies according to individual preferences. For example, there are various ways for learners to make notes (including handwritten and typing on a digital device) as well as various study tools for making notes (including posters and Post-it notes) (Witherby & Tauber, 2019). Student responses to the open-ended questions reflected how students' applied these more versatile learning strategies during independent study. Some strategies are more versatile than others in terms of how they can be applied, and this might have resulted in more students reporting on these strategies in the open-ended answers compared to other less versatile approaches. Future research using qualitative methods (i.e., semi-structured interviews, focus groups) is needed to understand the variation in secondary students' strategy use and the reason behind those choices.

### *4.6. Implication for Educators*

The present study highlights the need to improve students' awareness about the relative utility of learning strategies. In particular, our results suggest that as an important first step, learners would benefit from receiving additional guidance in how to use higher utility learning strategies such as retrieval and spaced practice. Our results also suggest that educators should inform students about: (1) which are the more and less effective learning strategies; (2) the benefits of using retrieval and spaced practice as learning strategies; and, (3) how each strategy works and the practical application for independent study.

*4.7. Strengths and Limitations*

We acknowledge some limitations in the current study. The authors did not collect information on students' opinions of other learning strategies that they might use less frequently to study and revise in preparation for science examinations. A limitation of conducting any survey research is the reliance on self-reporting to gather information on learner behaviours. However, it was not possible to undertake direct observations of learners' study practice, especially when studying at home. The aim of the study was to evaluate what learning strategies students use for their independent study and revision in preparation for examinations (i.e., learning outside of the classroom settings) and, therefore, this was not something that could be easily collected due to the practical and resource limitations of the project. There was some survey non-response reported at the school and student level. However, as we used a probability sampling method, we were able to use survey weights to overcome some of the potential non-response imbalances in the survey findings.

Despite these limitations, this is the first study to report on secondary students' study and revision habits from a representative sample of 14 to 15 year old students in mainstream schools in the UK. As our responses included a stratified, random sample of learners from different ability groups, the results are less likely to be biased towards over- or under-reporting due to students who were more or less interested in study and/or revision. Also, the findings are less likely to be distorted due to the potential under-representation of student groups.

## 5. Conclusions

This is the first study to employ a robust sampling methodology aimed at gaining a more accurate understanding of secondary school students' use and understanding of learning strategies to study and revise independently in preparation for GCSE science examinations in the UK. We evaluated students' use and understanding of a range of commonly used learning strategies in schools, including some of the higher and lower utility approaches described by Dunlosky et al. (2013) (Table 1). We also evaluated the effort students make towards independent learning and the study advice schools provide to students. These findings formed part of an evaluation project commissioned by the north Wales regional school improvement service (GwE) in an effort to provide a comprehensive insight into students' independent learning habits. Our results indicate that students predominantly rely on less effective strategies for independent study and revision and do not know that some of the strategies they most frequently use have lower utility ratings. Importantly, students believe that some of these lower utility strategies are more helpful to them. They are also unaware of the benefits of using retrieval practice as an effective strategy that can be used with a range of materials and learning conditions (i.e., flashcards). In addition, students do not utilise their study time evenly, and this is likely to be a significant impediment to the use of higher utility strategies such as spaced practice. Together, these findings provide important information for schools as they work towards helping students make better use of their independent learning to improve outcomes. Further research should now: (1) focus on the practical barriers to secondary students' use of effective learning strategies; and, (2) explore whether students' use of learning strategies predicts their actual learning outcomes.

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**Data Availability Statement:** The data that support the findings of this study are available from the corresponding author, F.S., upon reasonable request.

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