

Article

# Effects of Block vs. Traditional Scheduling on High School Science Success—Lessons from Biology Classes

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**Abstract:** Many studies investigate the effects of block vs. traditional class scheduling on the students' success in high-school science classes. However, it is rare for studies to investigate the interactive effect of class scheduling and students' average performance on the students' success. We investigated how block (B) vs. single (S) class scheduling, students' average performance and their interaction affect students' success in high school biology course. The study included 281 high school students (1st to 4th grade; 124 students from S-, 157 from B-scheduled classes) participating in: (1) first written exam conducted to evaluate students' initial knowledge; (2) teaching in block- vs. single-scheduled classes; (3) second written exam conducted to assess students' achievement after block- vs. single-scheduled classes. Block-scheduled classes improved students' performance in 3rd grade only. In 1st and 2nd grade, students from single-scheduled classes achieved better results. In 4th grade, there was no significant difference in success among block- vs. single-scheduled classes. Block-scheduled classes did not affect students' success equally across all student performance categories. When estimating the effects of class scheduling on students' success, students' age, prior knowledge, overall performance and complexity of educational topics should be considered.

**Keywords:** student achievement; student performance categories; class scheduling; prior knowledge

## 1. Introduction

Whereas many studies investigate the effects of block vs. traditional class scheduling on the students' success in high school science classes (see reviews by [1,2]), rare studies have considered the respective interactive effect of the class scheduling and students' average performance. Thus, in this paper, we investigate how block- vs. single-class (traditional) scheduling, students' average performance and their interaction affect students' success (i.e., exam score) in high school biology course. Our findings could provide valuable information for successfully tailoring STEM instruction, which often depends on the differently time-framed learning modes and abilities as well as on the students' interests and overall performance [3]. If proven in the present study, potential benefits of the block-scheduled teaching can be used in the process of implementing ongoing curriculum changes in several European countries (e.g., Belgium, Croatia, Estonia, Latvia, Poland) as from primary education [4,5].

In addition to being relevant for the development of national curricula (and associated recommendations for learning, teaching and assessment), our findings on the effects of block vs. traditional scheduling within biology classes could serve as guidelines for the curriculum

development at other educational levels (e.g., individual educational institutions, classes, subjects, teachers and students), including STEM curricula. The ongoing curricular reforms within STEM subjects are greatly targeted towards emphasizing scientific approach in teaching [5]. The scientific approach is recognized to contribute to the development of students' skills and attitudes (e.g., critical thinking and argumentation based on evidence and logical reasoning) applicable in everyday life (cf. [6,7]). However, the scientific approach is often difficult to apply in traditional class scheduling due to specific time requirements for some STEM learning contents and activities (e.g., long-termed observations in biology vs. short-termed experiments in physics) [8].

The success of the instructional strategies teachers select can thus be affected by course scheduling, i.e., whether the classes are single- (traditionally) or block-scheduled (cf. [1]). There are different variations of block scheduling, but it primarily refers to the 90-min class periods as opposed to the traditional (single) 45 min classes [2]. By extending class periods, the block-scheduled setup reduces instructional fragmentation and increases instructional variety, mostly by promoting flexible, innovative and creative teaching, including active learning strategies [1,9–13]. Many practitioners and teachers have observed that larger blocks of time allocated to specific topics allow effective collaborative, peer-based and inquiry-led teaching and learning, which likely improve student performance [12,14,15]. Thus, block-scheduled teaching can provide optimal and appropriate exchange of the activities among students and their teachers, which can further lead to effective application of classroom-gathered knowledge to real-world problems (cf. [16]). However, several scientific studies have shown that block scheduling may hinder actual student achievement in several areas (including math, biology and chemistry), mostly due to limitations in the students' attention span, particularly at certain age and developmental stages ([17,18] and references therein). Additionally, a considerable amount of literature has highlighted that changes in course gaps and/or course sequence caused by block scheduling may diminish consistency in student learning, knowledge retention and student achievement in science courses (e.g., [19–23]). According to the in-depth review by [2], which was based on a meta-analysis of 12 studies dealing with the effectiveness of different types of block scheduling on students' achievement (exam scores) across different subjects, block scheduling generally results in higher cross-subject achievement than traditional scheduling. However, when separately considering the effects of particular types of block scheduling (i.e.,  $4 \times 4$ , A/B and hybrid block schedule) on the exam scores of individual subjects, there is no clear evidence of the absolute block-schedule efficiency. The meta-analysis pointed out that for science classes, block (vs. traditional) scheduling yields higher exam scores, whereas for math and language classes, there was no clear evidence to suggest that block scheduling would be more or less effective than traditional scheduling [2].

Besides the time available to master certain teaching contents, students' academic performance and knowledge retention in science courses greatly depend on the students' subject-specific prior knowledge, motivation to learn, and the way science is taught at (high) school levels (cf. [24,25]). Generally, students with a higher prior knowledge demonstrate higher motivation and conceptual understanding during further learning of a certain scientific topic, and perform better on the exams [26,27]. Such students are likely to benefit from further education and learning opportunities throughout life. However, previous studies have evidenced that students' motivation to learn tends to decline during early adolescence, after the transition from primary to secondary school [24,28,29], and it may affect the temporal consistency of the students' performance and knowledge retention. Thus, many science instructors at the high school level are challenged by identifying how to teach specific content with specific instructional strategies to continuously gain students' interest and motivation, content knowledge and disciplinary competencies [30,31].

Our research objective was to investigate the effect of block- vs. single-class (traditional) scheduling, students' average performance and their interaction on the students' biology exam score across four high school grades. Following previous findings on the benefits of block scheduling regarding the students' success at science classes [12,14,15], we hypothesized that block scheduling would result in increased students' success (higher biology exam score) regardless of the students' average performance.

We have chosen to test our hypotheses within biology classes, as biology is one of the first scientific courses in formal school education, providing important basic knowledge for a broad range of career interests in students' further education (e.g., medicine, pharmacy, nursing, stomatology, biomedicine, environmental science, etc.), thus representing a source of important prior scientific knowledge for many students. In this study, students' average performance was assessed as a mean score between the two consecutive exams—initial written exam (applied before block- vs. single-scheduled teaching) and second exam (applied after block- vs. single-scheduled teaching). The two exams permitted us to test our hypothesis with two sets of data, providing us a more detailed insight into the scale of the (interactive) effect of class scheduling and students' average performance on the students' success. By dividing students into four performance categories (low, medium, good, and excellent), based on the mean score between the two exams, we were able to assess which students (i.e., different student performance levels) might be benefiting from block vs. single scheduling of biology classes.

The remainder of this paper is organized as follows. Section 2 describes the methodology applied in this study, including the descriptions of the student population participating in the study and the three research stages: (1) the first written exam used to assess students' initial knowledge before block vs. single biology class scheduling; (2) teaching within a block vs. single schedule; (3) the second written exam used to assess student achievement after block vs. single biology class scheduling. Section 2 also describes the data sets and statistical methods used for the assessment of the interactive effect of the class scheduling and students' average performance on student achievement. In Section 3 the results of the analyses are presented. Section 4 discusses our findings in relation to the objectives of the study, considering the study limitations. Section 5 provides conclusions based on our findings.

## 2. Materials and Methods

### 2.1. Student Sample and Study Design

The population-based sample consisted of 281 Croatian students aged 15 to 18 years (i.e., students of first to fourth grade of secondary school (i.e., gymnasium); mean age  $\pm$  SD = 17.2  $\pm$  0.43). Students' parents provided written consent prior to their child's participation in the study, and the study protocol was approved by the ethics committee of the participating schools' directorate. Student structure, educational topics and instructional strategies (i.e., teaching activities) applied in each grade are presented in Table 1.

The students were divided into two groups differing in the class scheduling:

1. Single-scheduled classes (S; 124 student sample)
2. Block-scheduled classes (B; 157 student sample).

The single lesson refers to a lesson that takes 45 min and takes place twice a week, whereas block classes take place once a week and last 90 min. The student groups were taught biology the same way (S vs. B) before and during this research, and they were balanced regarding thematic schedule of biology lessons within a certain grade.

The research consisted of three stages adjusted to students' age and thematic schedule of biology classes within a certain grade. In the first stage, all students took the same grade-specific initial written exam consisting of 20 questions designed for this study (1st written exam), so we could assess the achieved learning outcomes assigned to the specific topic (Table 1), and students' knowledge acquired before our further investigation, respectively. The second stage was teaching. To ensure the teaching style uniformity, each teacher (in total eight teachers) received uniform ready-to-use lesson plans for each educational topic targeted to achieve a uniform teaching mode coupled with a set of desired learning outcomes and linked concepts within each grade (Table 1).

**Table 1.** Overview of the student structure, educational topics, learning outcomes and applied teaching activities within the present study. N—sample size (number of classes included in the study within each grade; number of students in each group).

Grade	Student Age	Educational Topics	Learning Outcomes (Students Are Able to . . . )	N	Teaching Activities
1st	15	<i>Cell biology</i>	<ul style="list-style-type: none"> <li>- recognize eukaryotic and prokaryotic cell types;</li> <li>- integrate structure and function of individual cell organelles;</li> <li>- discuss the differences between animal and plant cells.</li> </ul>	N (classes) = 3 N (students) = 61	Practical work (hands-on investigation of living cells and cell models), observation and demonstration with drawing and discussion.
2nd	16	<i>Protoctista and fungi</i>	<ul style="list-style-type: none"> <li>- analyze characteristics of the main autotrophic and heterotrophic groups of Protoctista, and explain their role in the biosphere;</li> <li>- indicate characteristics of fungi and explain their role in the biosphere.</li> </ul>	N (classes) = 4 N (students) = 103	Practical work (hands-on investigation of living cells and cell models), discussion, observation and demonstration with drawing and discussion.
3rd	17	<i>Human digestive system</i>	<ul style="list-style-type: none"> <li>- explain the structure, layout and primary function of the digestive system within human body;</li> <li>- discuss the importance of a healthy lifestyle for the digestive system.</li> </ul>	N (classes) = 3 N (students) = 57	Observation and demonstrations of models, watching an educational video followed by student discussions and content systematization, drawing and oral presentation with discussion.
4th	18	<i>Gene structure and function</i>	<ul style="list-style-type: none"> <li>- explain molecular basis, structure and function of genes and their importance for the inheritance.</li> </ul>	N (classes) = 3 N (students) = 60	Observation and demonstrations of models, drawing, watching an educational video followed by student discussions, content systematization and oral presentation with discussion.

A certain number of students (i.e., student classes) within each grade were taught by implementing single-scheduled lessons (one topic within a single 45-min lesson)—after two days, these students were taught another conceptually related topic within the single-scheduled lesson scheme. At the beginning of the new lesson/related topic, students repeated the contents taught in the previous lesson. Students exposed to block-scheduled lessons studied both conceptually related topics in a single day over 90 min. Eventually, the same teaching methods and learning outcomes were achieved at both block- and single-scheduled classes, but the classes set-up was different in terms of temporally ‘merging’ vs. ‘splitting’ conceptually related topics, respectively. For example, in the 1st grade, within block-scheduled classes students were simultaneously taught about differences between prokaryotic and eukaryotic cells, while within single-scheduled classes, each cell type was taught in a separate single class, etc. (see Table 1 for educational topics taught in other grades).

The third stage involved the implementation of another grade-specific written exam (2nd written exam), consisting of 20-questions designed specifically for this study. Students of each grade took the same written exam, so we could assess the same learning outcomes as with the 1st written exam (Table 1), and student achievement after block vs. single scheduling, respectively. The 1st and 2nd written exams were not the same, but they examined the same learning outcomes and linked concepts. The educational topics and learning outcomes for this research were selected according to the Croatian national program for secondary education [32].

## 2.2. Statistics

Descriptive statistics was first used to represent general trends of the students’ success (i.e., overall student achievement) at 1st and 2nd written exams. In order to get a better insight into the student performance, we defined the four overall performance categories: low < 40%, medium 40–69%, good 70–89%, and excellent 90–100%, based on the mean percentage of student exam success at both exams (1st and 2nd written exam). We first applied a t-test on the 1st written exam score within each grade, to test whether students taught in block- vs. single-scheduled lessons initially differed in their performance. We then conducted a two-way ANCOVA to determine if there was a statistically significant two-way interaction effect between grade (i.e., a proxy of students’ age) and class scheduling (block vs. single) in terms of students’ final exam performance (2nd written exam score), after adjusting for the students’ overall performance (covariate: mean percentage of student exam success at both exams). This analysis was followed by an one-way ANCOVA for each grade separately, to test whether there was an effect of class scheduling on students’ final (i.e., 2nd) exam performance after controlling for overall students’ performance within each grade. We additionally conducted an one-way ANOVA (followed by the Unequal N HSD post-hoc test) to determine if there was a statistically significant effect of students’ performance category on the students’ performance (written exam score) at both exams (i.e., 1st and 2nd written exam) within each grade separately. In addition, we have grouped students according to the ‘performance category\*class scheduling’ into the following groups: low\*B, medium\*B, good\*B, excellent\*B, low\*S, medium\*S, good\*S, excellent\*S. Then, we conducted an one-way ANOVA (followed by the Unequal N HSD post-hoc test), to determine if there was a statistically significant difference in the students’ 1st and 2nd written exam scores depending on the ‘performance category\*class scheduling’ grouping. All data (1st and 2nd exam scores, mean percentage of student exam success at both exams) were  $\log(x + 1)$  transformed before analysis to correct for non-normal distribution. All data analyses were conducted using statistical package Statistica version 13.3., TIPCO Software Inc. (Palo Alto, CA, USA).

## 3. Results

Mean ( $\pm$ standard deviation, SD) written exam scores for the 1st and 2nd written exam score of the students exposed to single- and block-scheduled lessons within each grade (1st, 2nd, 3rd, 4th) are shown in Figures 1–4. Mean percentage of completion at both exams in each grade were: 72% ( $\pm$ 14%) in 1st grade, 58% ( $\pm$ 16%) in 2nd grade, 75% ( $\pm$ 16%) in 3rd grade and 69% ( $\pm$ 17%) in 4th

grade. A t-test applied on the 1st written exam score within each grade indicated that initially, in most (1st, 3rd, 4th) grades, there was no significant difference (t-test,  $p > 0.05$ ) in the students' written exam performance between block and single classes, indicating that both groups were equal in previous knowledge. In 2nd grade, students attending single-scheduled classes performed significantly better at the 1st written exam than their colleagues from block-scheduled classes (t-test,  $t = -3.10948$ ,  $p < 0.01$ ). A two-way ANCOVA applied on the entire data set (i.e., all grades: 1st, 2nd, 3rd, 4th) indicated a significant two-way interaction effect of grade (i.e., a proxy of students' age;  $F = 10.2$ ,  $p < 0.001$ ) and class scheduling (block vs. single;  $F = 6.2$ ,  $p < 0.05$ ) on the students' final exam performance (2nd written exam score), after adjusting for the students' overall performance. The interactive effect of the overall students' performance and grade (i.e., students' age) was also proven ( $F = 4.7$ ,  $p < 0.001$ ). Thus, this analysis was followed by a one-way ANCOVA for each grade separately, to test the effects of class scheduling on students' final exam performance after controlling for overall students' performance within each grade. The one-way ANCOVA applied on the 2nd written exam scores confirmed a statistically significant difference in students' success between single- vs. block-scheduled biology classes within 1st, 2nd and 3rd grade, whereas in the 4th grade, the statistically significant difference was not confirmed (Table 2, Figures 1a, 2a, 3a and 4a).

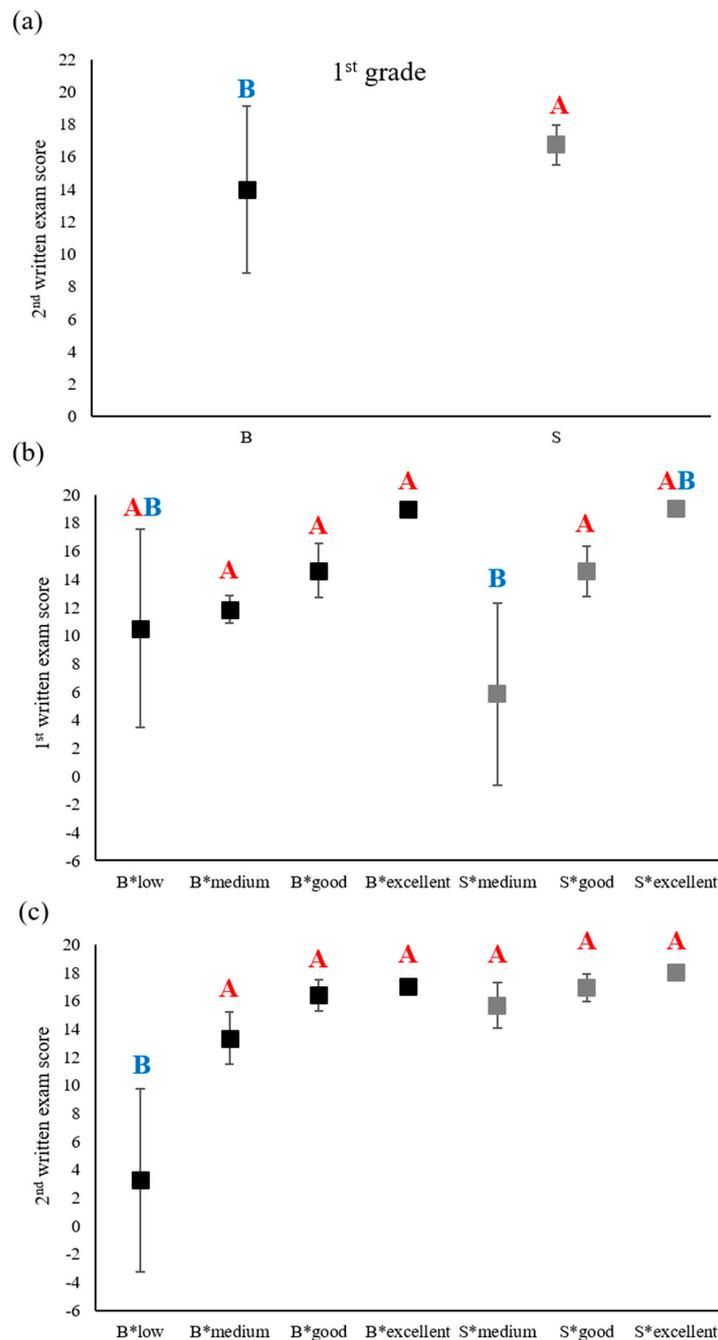
**Table 2.** Summarized ANCOVA results for the effects of class scheduling (block vs. single), overall students' performance (i.e., covariate: mean percentage of student exam success at both exams), and interaction of class scheduling and overall students' performance on the students' success (exam score) in the 2nd written exam. Abbreviation: *df*—degrees of freedom, *F*—test statistic for ANCOVA, *p*—level of significance (bolded values are significant, i.e.,  $p < 0.05$ ).

	Effect	<i>df</i>	<i>F</i>	<i>p</i>
1. grade	Block vs. Single	1	37.52	<b>0.000</b>
	Overall students' performance	1	39.70	<b>0.000</b>
	Interaction: Block vs. Single * Overall students' performance	1	34.31	<b>0.000</b>
2. grade	Block vs. Single	1	29.83	<b>0.000</b>
	Overall students' performance	1	98.58	<b>0.000</b>
	Interaction: Block vs. Single * Overall students' performance	1	30.67	<b>0.000</b>
3. grade	Block vs. Single	1	7.48	<b>0.008</b>
	Overall students' performance	1	22.43	<b>0.000</b>
	Interaction: Block vs. Single * Overall students' performance	1	6.45	<b>0.014</b>
4. grade	Block vs. Single	1	2.49	0.120
	Overall students' performance	1	6.41	<b>0.014</b>
	Interaction: Block vs. Single * Overall students' performance	1	1.92	0.172

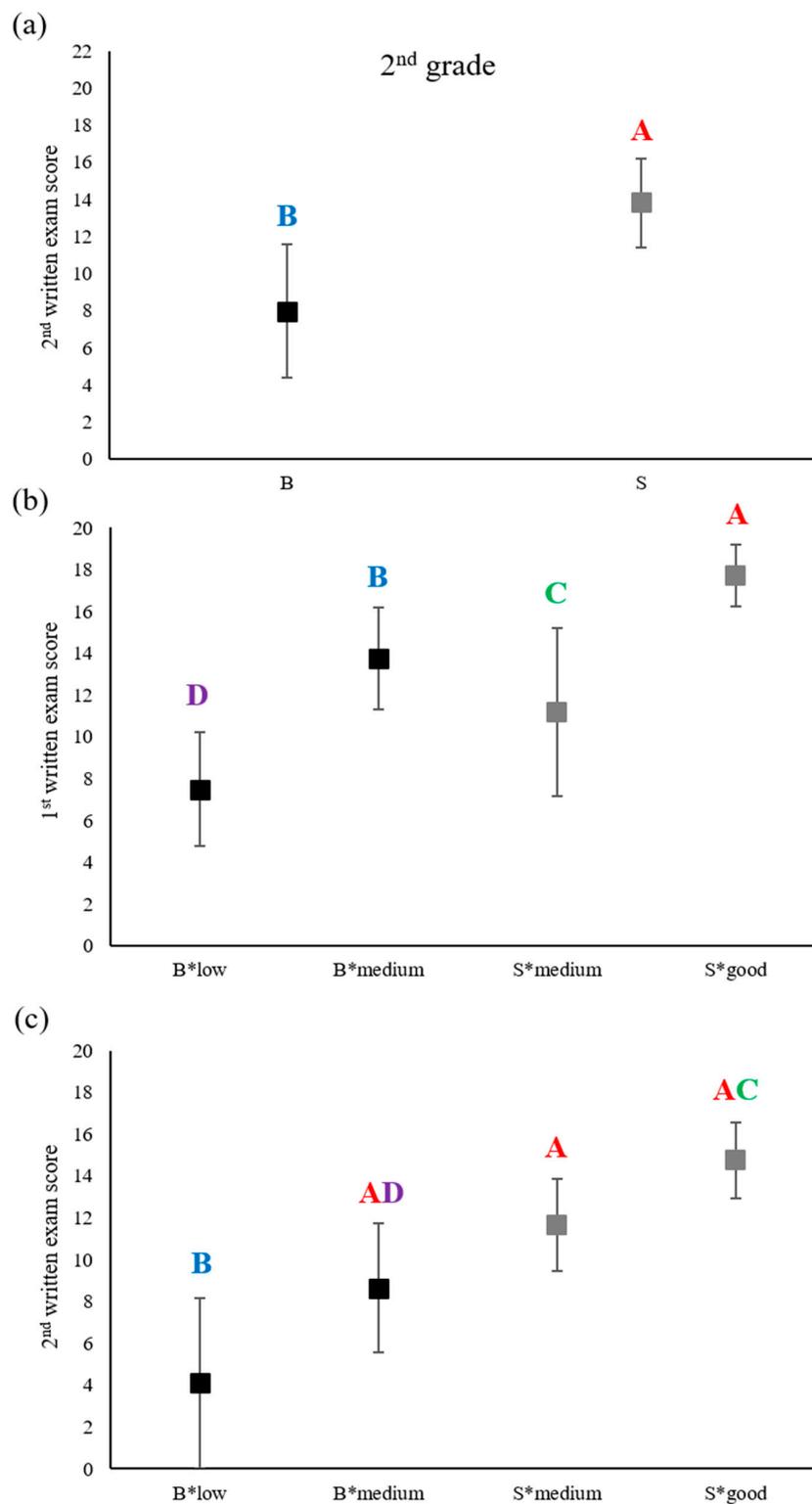
Among single-scheduled 1st graders, there were no students belonging to low-performing student category. According to the ANCOVA results, 1st grade students exposed to single-scheduled biology classes performed significantly better in the 2nd written exam than students attending block-scheduled classes (Figure 1a, Table 2). The interactive effects of the overall students' performance (student performing categories) and class scheduling were also proven (Tables 2 and 3). Taking into consideration this interactive effect and students' success on both (1st and 2nd) written exams, it was proven that block vs. single scheduling did not equally affect the students' success across all student performance categories.

Generally, when comparing 1st and 2nd written exam scores in 1st grade, medium and good-performing students reached the success of excellent students, whereas low-performing students did not make any progress (moreover, they had worse success) in the 2nd written exam (Figure 1b,c, Table 3). Block-scheduled 1st graders of all student performance categories had consistent scores in the 1st written exam, whereas in the 2nd written exam, low-performing students taught in block classes deteriorated in success (Figure 1b,c). Within single scheduled 1st grade biology classes, medium-performing students had significantly lower scores in the 1st written exam than

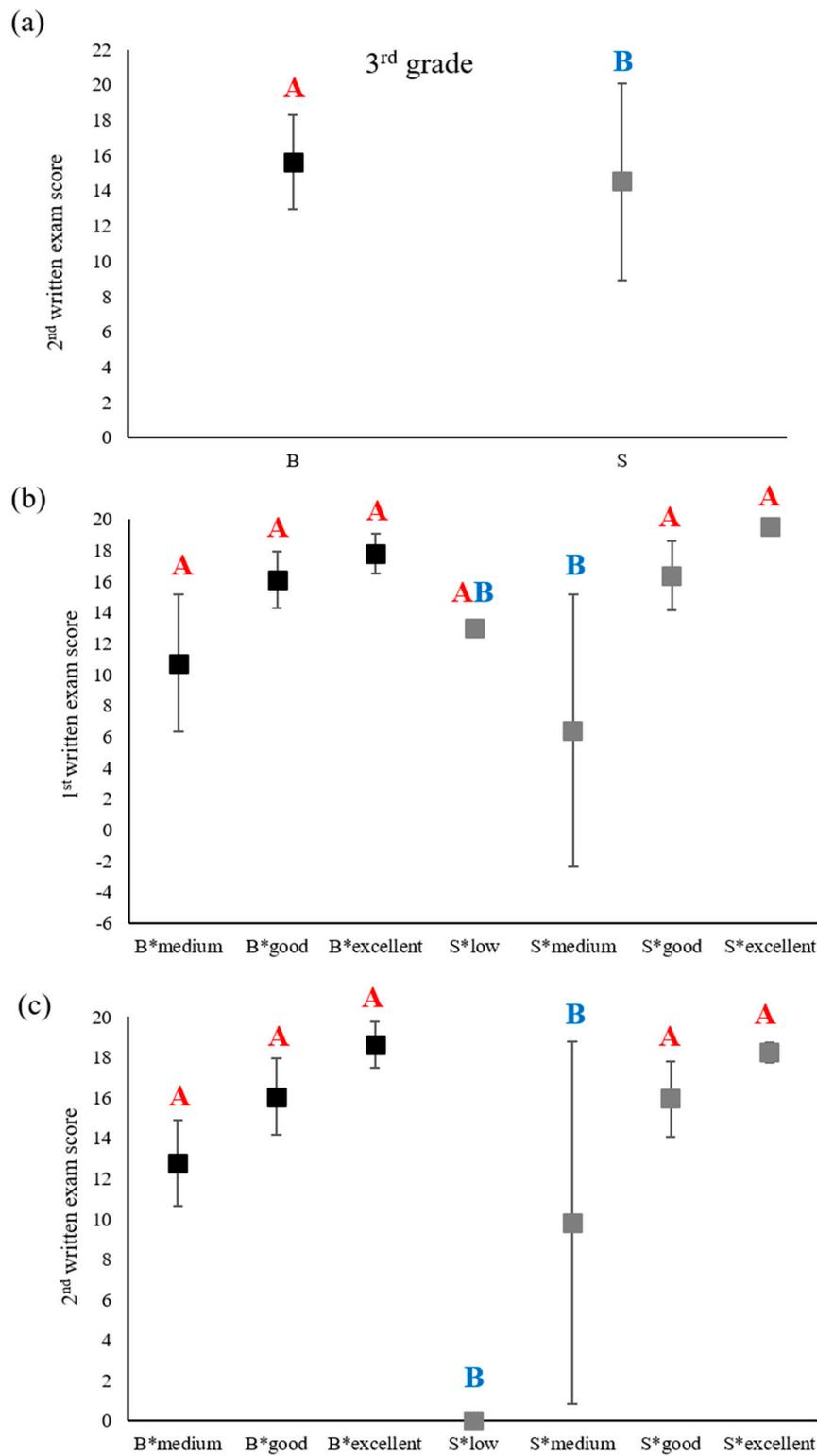
good-performing students. However, in the 2nd written exam, all student performing categories had equal success. Thus, excellent and good 1st grade students performed equally well after teaching in block- and single-scheduled classes, single-scheduled teaching had improvement effect on the performance of students belonging to medium student performance category, whereas block-scheduled teaching had deteriorating effect on the low-performing students' performance (Figure 1b,c).



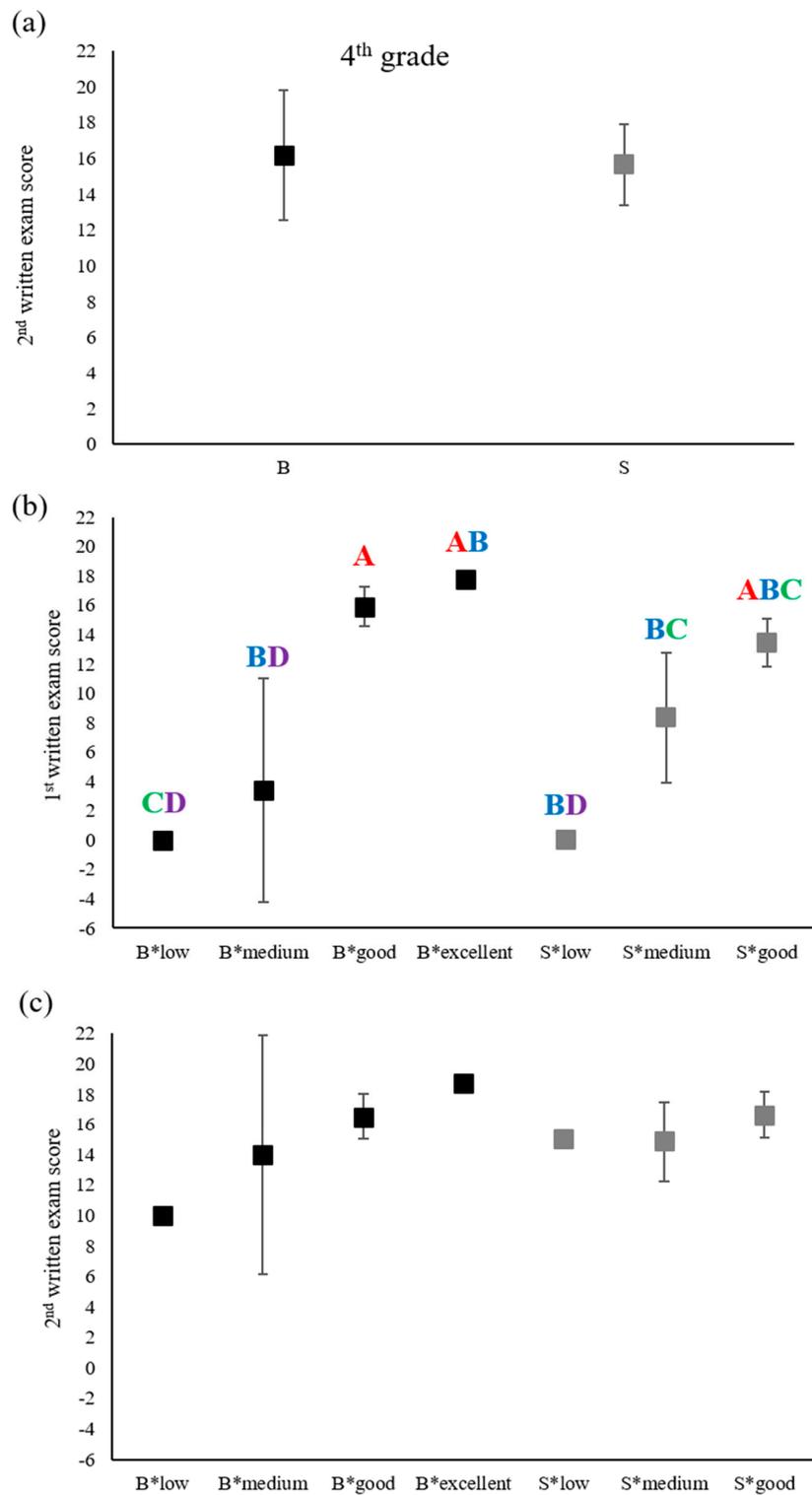
**Figure 1.** Mean ( $\pm$ SD) written exam scores among the first grade students: (a) after teaching within block vs. single scheduled biology classes (i.e., at the 2nd written exam); (b) for different performance categories and biology class scheduling at the 1st written exam; (c) for different performance categories and biology class scheduling at the 2nd written exam. Colored letters A and B denote significant differences among individual student groups (according to the Unequal N HSD post-hoc test). Groups denoted by the same letter are not significantly different from each other. The detailed statistical analysis results are given in Tables 2 and 3.



**Figure 2.** Mean ( $\pm$ SD) written exam scores among the second grade students: (a) after teaching within block vs. single scheduled biology classes (i.e., at the 2nd written exam); (b) for different performance categories and biology class scheduling at the 1st written exam; (c) for different performance categories and biology class scheduling at the 2nd written exam. Colored letters A, B, C and D denote significant differences among individual student groups (according to the Unequal N HSD post-hoc test). Groups denoted by the same letter are not significantly different from each other. The detailed statistical analysis results are given in Tables 2 and 3.



**Figure 3.** Mean ( $\pm$ SD) written exam scores among the third grade students: (a) after teaching within block- vs. single-scheduled biology classes (i.e., at the 2nd written exam); (b) for different performance categories and biology class scheduling at the 1st written exam; (c) for different performance categories and biology class scheduling at the 2nd written exam. Colored letters A and B denote significant differences among individual student groups (according to the Unequal N HSD post-hoc test). Groups denoted by the same letter are not significantly different from each other. The detailed statistical analysis results are given in Tables 2 and 3.



**Figure 4.** Mean ( $\pm$ SD) written exam scores among the fourth grade students: (a) after teaching within block vs. single scheduled biology classes (i.e., at the 2nd written exam); (b) for different performance categories and biology class scheduling at the 1st written exam; (c) for different performance categories and biology class scheduling at the 2nd written exam. Colored letters A and B denote significant differences among individual student groups (according to the Unequal N HSD post-hoc test). Groups denoted by the same letter are not significantly different from each other. The absence of letters indicates that there is no significant differences between the analyzed groups. The detailed statistical analysis results are given in Tables 2 and 3.

**Table 3.** Summarized ANOVA results for the effects of student performance category and class scheduling \* performance category on the students' success (i.e., exam score) in the 1st and 2nd written exam. Abbreviation: *df*—degrees of freedom, *F*—test statistic for ANCOVA, *p*—level of significance (bolded values are significant, i.e.,  $p < 0.05$ ).

	Grade	Effect	<i>df</i>	<i>F</i>	<i>p</i>
1st written exam	1st	Performance category	3	7.29	<b>0.000</b>
	2nd		2	54.41	<b>0.000</b>
	3rd		3	9.66	<b>0.000</b>
	4th		3	22.35	<b>0.000</b>
	1st	Class scheduling * Performance category	6	7.34	<b>0.000</b>
	2nd		3	44.10	<b>0.000</b>
	3rd		6	7.72	<b>0.000</b>
	4th		6	17.16	<b>0.000</b>
2nd written exam	1st	Performance category	3	61.29	<b>0.000</b>
	2nd		2	47.45	<b>0.000</b>
	3rd		3	14.95	<b>0.000</b>
	4th		3	1.79	0.16
	1st	Class scheduling * Performance category	6	29.60	<b>0.000</b>
	2nd		3	34.99	<b>0.000</b>
	3rd		6	10.74	<b>0.000</b>
	4th		6	1.80	0.116

In 2nd grade, students exposed to single-scheduled biology classes also performed significantly better in the 2nd written exam than block-scheduled students (Figure 2a, Table 2). ANCOVA also confirmed the interactive effects of the overall students' performance (student performing categories) and class scheduling in 2nd grade (Tables 2 and 3). In 2nd grade, only low, medium and good student performance categories existed (Figure 2b,c). In the 1st written exam, all (low, medium and good) student categories significantly differed in their success (Table 3), whereas in the 2nd written exam, medium and good-performing students equalized in their success (Figure 2b,c). In both (1st and 2nd) written exams, medium-performing students taught in block-scheduled classes achieved significantly higher exam score than low-performing students (Figure 2b,c). Within single scheduled biology classes in 2nd grade, in the 1st written exam, medium-performing students had significantly lower scores than good-performing students, but in the 2nd written exam, the significant differences between the two student performing categories were lost (i.e., medium-performing students approached the success of the good students) (Figure 2b,c). Thus, in 2nd grade, block-scheduled classes did not result in changing the students' performance, whereas single-scheduled classes resulted in improving the performance of the students belonging to the medium student performance category.

In 3rd grade, students exposed to block-scheduled biology classes performed significantly better in the 2nd written exam than students attending single-scheduled classes (Figure 3a, Table 2). The interactive effects of the overall students' performance (student performing categories) and class scheduling were also proven (Tables 2 and 3). In 3rd grade, within block-scheduled classes, there were no students belonging to the low-performance category (Figure 3b,c). In general, in the 1st written exam, students belonging to medium student performance category achieved significantly lower exam scores than good and excellent students (Table 3). In the 2nd written exam, good and excellent students performed significantly better than both medium and low student performance categories (Table 3). Additionally, medium student performance category performed significantly better than low-performing students in the 2nd written exam (Table 3). In block-scheduled classes, all student performance categories (medium, good, and excellent) performed equally well at both (1st and 2nd) written exams (Figure 3b,c). In single-scheduled classes, at the 1st written exam, medium-performing students performed significantly worse than good and excellent students, whereas low-performing students did not significantly differ neither from medium nor from good and

excellent students (Figure 3b). In comparison to the 1st written exam, at the 2nd written exam in the single-scheduled classes, low-performing students deteriorated in their success, so they performed significantly worse than good and excellent students (Figure 3c, Table 3). Thus, medium, good and excellent 3rd grade students performed equally well after teaching in block- and single-scheduled classes, whereas single-scheduled teaching had deteriorating effect on the performance of students belonging to low student performance category.

In 4th grade, there were no significant differences in the 2nd written exam score between students exposed to block- vs. single-scheduled biology classes (Figure 4a, Table 2). Whereas ANCOVA results indicated that overall students' performance had a significant effect on the 2nd written exam score in 4th grade, the respective interactive effects of the overall students' performance (student performing categories) and class scheduling were not proven (Tables 2 and 3). In 4th grade, within single-scheduled classes, there were no students belonging to excellent performance category (Figure 4b,c). In the 1st written exam, low-performing students generally achieved significantly lower exam scores than medium, good and excellent students (Figure 4b). In the 2nd written exam, students belonging to low and medium performance categories (in both, block- and single-scheduled classes) were successful in approaching the success of good and excellent-performing students, so between-group differences that existed at the 1st exam disappeared (Figure 4b,c, Table 3). Thus, in 4th grade, good and excellent students performed equally well, whereas low and medium-performing students improved in their performance at the 2nd written exam, no matter how they were taught.

#### 4. Discussion

Many previous debates on the challenges of block scheduling within science classes have tried to disclose whether block scheduling can enhance learning and instruction opportunities for students and teachers, or it rather fails to enhance academic performance [9,17,18,23,33] and references therein]. Our hypothesis that block scheduling will lead to increased students' success regardless of the students' performance category has been partially proven. Based on our findings, we suggest that, when estimating the effects of class scheduling on students' success (i.e., exam performance), students' age, grade and levels of cognitive development as well as their prior knowledge (i.e., complexity of the pre-existing knowledge) and the complexity and 'attractiveness' of educational topics should be considered. Other studies investigating biology and/or higher education knowledge practices have also suggested that students' intelligence, prior knowledge and learning approach are good predictors of the students' achievement [34,35]. Providing evidence that block-scheduled biology classes can have positive effects on success and knowledge retention of some students, our study adds to the observations that teaching of certain educational topics within block-scheduled science classes can enhance learning process at certain students' age and/or performance category [11,17,36]. However, block scheduling does not necessarily change student motivation and goal orientation, the way teachers plan and frame their lessons and/or teach and interrelate core concepts, nor it necessarily affects the topics and content presented to students [37,38]. Thus, many different influences might have contributed to the differences observed across different student ages (i.e., grades) and performing categories within the present study.

##### 4.1. Effect of Class Scheduling on Students' Exam Performance within Each Grade

Considering the general effect of block- vs. single-class (traditional) scheduling on the students' written exam success, our findings indicate that block-scheduled (vs. single-scheduled) classes improve students' performance in 3rd grade only. In 1st and 2nd grade, students achieved better results after being taught within single-scheduled biology classes, while in 4th grade, students attending block-scheduled classes demonstrated the same success as the students who attended the single-scheduled classes. Some studies suggest that block scheduling can improve students' performance, especially in low-performing schools [12,17,39], some suggest that traditional scheduling (i.e., single classes)

result in higher test scores [40,41], whereas [42] did not find a significant difference in biology exam scores between traditional and blocked high school schedules.

Our results can be discussed from the aspect of (i) students' prior (initial) experience in block-scheduled classes, (ii) subject (i.e., biology) target topics, key concepts and associated learning outcomes and/or (iii) students' ability to link and relate concepts independently, by using their prior knowledge.

Due to their longer duration, block-scheduled classes enable successful building and connection of concepts, which is usually facilitated by employing teaching methods requiring active cognitive student engagement [11,17,36]. The positive impact of block scheduling has mainly been observed in the context of studying complex topics and/or science laboratories [36,43]. The authors of [15] and [23] suggested that block scheduling enables students to focus on one specific subject for a longer period, whereas [44] indicated that an advantage of block scheduling is the possibility to learn multiple similar topics simultaneously and/or to work continuously on the same teaching project that fosters a certain concept.

It is likely that some topics (e.g., eukaryotic and prokaryotic cell types in the 1st grade, and protocista and fungi in the 2nd grade) and associated learning outcomes do not necessarily gain the benefits (in terms of enhanced students' performance) of extended block scheduling. In this research, 1st and 2nd grade students were exposed to practical work (Table 1) mainly oriented towards gaining the ability to analyze structural characteristics of different cell types and organisms. Although the practical work was involved, it is likely that the examined 1st- and 2nd-grade topics were prevalently fact-oriented (i.e., loaded with much new scientific terminology), and thus difficult to absorb for students, who consequently missed out gaining an in-depth understanding, i.e., a threshold concept (cf. [45]). Within biology, threshold concepts are mostly related with topics involving processes (e.g., photosynthesis) and abstract ideas (e.g., genetics, evolution) in comparison to content-focused key concepts (e.g., structural and taxonomical organism features) (cf. [46,47]). It was not investigated whether 1st graders were taught biology within block- or single-scheduled classes during their primary school education, but the initial (1st) written exam results indicated that class scheduling did not significantly affect the 1st graders' performance. Thus, it is likely that the targeted topics and content-oriented approach (instead of class scheduling and prior knowledge) mostly affected the 1st graders exam performance. Furthermore, 1st grade students are at the beginning of their high school education, and we can assume that their prior knowledge is rather constrained when compared to 2nd, 3rd and 4th grade students, and they are likely still adjusting to the high school circumstances. These students might need more time to adjust to a new learning environment and focus on organizing their work (cf. [48,49]). Due to focusing more on the novel schedule and related activities, students might further lose the focus on the core content (i.e., concepts to be learned based on the activities), and their academic performance might not be as optimal as expected.

Moreover, students who lack proper schemes for integrating new information (due to gaining their prior knowledge within unguided environments, i.e., by 'self-exploration' of highly complex topics) may generate a heavy working memory load, which can be detrimental for learning [50–52]. This problem could be compensated by employing a certain 'stepwise approach', i.e., single instead of block class scheduling, in a way that each concept is taught individually within a single class, and then—at each next single class—everything that has been taught thus far is integrated and repeated. Additionally, considering the issues of students' interest and their attention span for certain topics, some learning topics and outcomes might be accepted and achieved better if a topic is covered in small (single) regular increments instead of a few large blocks (cf. [18]). It could be the case with 1st- and especially 2nd-grade topics and learning outcomes in this study that encompass many new terms associated to organisms' structure and taxonomy, and larger blocks eventually did not allow enough time for consolidation of the new and complex terminology. We suggest that the 'stepwise approach' is more efficient if applied during teaching less complex concepts and coupled with less demanding teaching activities, i.e., activities that can be completed within a single lesson and then regularly repeated.

By gradually repeating newly taught contents, students get a guidance in concept building and connecting, which can help them to better focus on a topic, and approach and frame their assignment [53]. Based on our findings of significantly better performance of students from single-scheduled (vs. block-scheduled) classes in 1st and 2nd grade (including the initial exam in 2nd grade), we suggest that quality guidance coupled with ‘stepwise’ teaching approach can be beneficial during teaching fact-oriented topics, such as those dealing with organisms’ structural characteristics in 1st and 2nd grade (Table 1). Thereby, due to introducing numerous organisms’ features, which are often accompanied by new and complex terminology, a quality teacher’s guidance is necessary for continuous systematization, repetition and/or consolidation of the individual facts, and fitting them into a larger picture (i.e., concept). Otherwise, if students lack adequate guidance and sufficient background knowledge of the subject matter, they could easily divert from the intended conceptual meaning and construct undesirable unscientific descriptions instead [53].

Prior knowledge supports the acquisition of new knowledge [54,55], and it gains importance as the educational level increases [56]. In 1st and 2nd grade, the anticipated concepts required many facts to be remembered and correctly connected to the students’ prior knowledge. In such circumstances, and according to our results, single-scheduled classes might provide better memory consolidation through regular repetitio [57]. In 3rd grade, students achieved better results when they learned within block scheduling, while the 4th grade students showed the same results regardless of the scheduling (single or block). This indicates that by growing the prior knowledge (i.e., by building more complicated knowledge network) during schooling, the degree of teacher’s assistance and leadership in conceptual linking may be dropping (which is likely to occur in 4th grade within this study). However, it is again necessary to consider topics and concepts expected to be built into already existing students’ knowledge. In 3rd grade, target topics are more complex (i.e., they require concept upgrade and logical connection with other topics associated to the organisms’ digestion concept), but they are likely to arouse students interest as students can easily relate to the topics concerning their own health, body and development. The topics that arouse student interest can help motivate students to learn and increase achievement [58]. In such context, we suggest that block lessons could additionally enhance learning by providing more time for building, interconnecting and discussing new and to students interesting concepts, which was likely reflected in improved results of the 2nd written exam in 3rd grade within this study. In 4th grade, the degree of students’ pre-existing knowledge is likely satisfactory, so the students could have easily mastered new content regardless of the way it was taught (in a block or in a single lesson).

#### *4.2. Performance Category as a Predictive Variable on Success Within Each Grade*

Initially, we hypothesized that block scheduling would result in increased students’ success (higher biology exam score) regardless of the students’ average performance. However, we have observed that block vs. single scheduling did not affect students’ success equally across all student performance categories. Our findings indicate that block-scheduled teaching generally does not have a significant effect on the success of good and excellent students (they seem to be successful regardless of the way they have been taught), whereas it can result in deteriorating success of low-performing students (as observed in 1st grade). We suggest that success of the differing student performing categories within each grade also greatly depends on the topic and associated learning outcomes, i.e., on whether the target topic is focused on facts (e.g., 1st- and 2nd-grade topics; Table 1) or on conceptual understanding (3rd- and 4th-grade topics; Table 1). It is likely that students respond differently to different topics, whereby some students are able to absorb many facts, without truly comprehending the concepts and retaining the information (cf. [59])—these students might excel in examining fact-focused knowledge. On the other hand, some students do not have capacity for quickly learning many new and complex terms, but they are highly reasoning-focused (cf. [60])—these students might fail (perform low) in examining fact-focused knowledge (i.e., 1st and 2nd grade topics), but they could perform excellent in examining conceptual understanding (i.e., 3rd and 4th grade topics).

Thus, accommodating students' personal preferences and profiles by offering multiple occasions with a variety of topics could give a better sense of student performance [61].

In general, the present study indicates that block scheduling employed with students who have less prior knowledge could cause adverse effects—it can cause a decline of students' success or it does not stimulate significant success (as observed among low and medium-performing students of 1st and 2nd grade). Only in 3rd grade, when the knowledge network has been enriched, due to the fact that students entered the second half of their high school education, block scheduling seems to enable better success among weaker (medium and low) performance categories. In 4th grade, success of all student performance categories equalized on the 2nd written exam. It indicated that students—when approaching the end of their high school education, and thereby gaining more experience and prior knowledge—can reach the same success level regardless of their overall performance (i.e., performance category) and/or class scheduling (block or single). Based on our results, single-scheduled teaching likely benefits the progress of students belonging to medium performance category (as observed in 1st and 2nd grade), but can cause deterioration of students' success within low student performance category (as observed in 3rd grade). The lower-performing students may benefit from the block-scheduled classes as such settings provide appropriate amount of teacher's attention and guidance (cf. [9]), which is not always available during single lessons. Reference [9] suggested that lower-performing students rather require extra time and guidance to successfully achieve the learning outcomes, whereas [20] indicated that low- to medium-ability students often require a lesser amount of information presented repeatedly over time in a variety of ways. Considering improved written exam scores of some low-performing students taught in block lessons (e.g., in 4th grade), we can suggest that the week-long time gaps between lesson blocks do not necessarily decrease the knowledge retention, as suggested by some authors [62]. If block lessons rely on quality teacher's instructions, active students' engagement including self-direction and collaborative inquiry in learning (instead of teacher-centered approach), it is likely that the lesson understanding and the longer-term knowledge retention will be better facilitated [20–23,63,64].

#### 4.3. Limitations of the Study

Our research is focused only on biology and it would be beneficial to relate students' success to overall students' performance (i.e., students' cognitive development and pre-existing knowledge) and class scheduling within other science classes as well. Another disadvantage is the circumstance that elementary school students have been excluded from the present study, so the observed age range of the students has been limited. Namely, Croatian education system consists of pre-school, elementary school, high school and higher education levels. Elementary education in Croatia is organized as a single-structure system, beginning at the age of six and consisting of eight years of compulsory schooling. High school education is not compulsory in Croatia, but almost all students enroll into the general (i.e., gymnasium) or vocational high schools upon completing elementary school. Gymnasium programs last four years, whereas vocational school programs can last three or four years, depending on the vocational field. In most Croatian elementary and high schools, students are placed in a single-grade class (e.g., 1st grade), based on their age (not on their performance). After the high school (and the final State Matura exam), students are allowed to enroll to Croatian higher education system, which comprises of university and professional study programs of different duration. STEM subjects within the Croatian elementary and high school education are aligned as follows. From the 1st to the 4th grade of elementary school, there are mathematics, and nature and society as two separate subjects. In the 5th and 6th grade of elementary school, mathematics, nature and informatics are taught separately, while in the 7th and 8th grade of elementary school, and during entire high school, most STEM subjects (e.g., mathematics, informatics, biology, chemistry, physics) are separate subjects. Biology is introduced in the 7th and 8th grade of elementary school. Conceptually, Biology subject builds on the subject Nature and society, which is taught from the 1st to the 4th grade of elementary school, and Nature, which is taught in the 5th and 6th grade of elementary school. Including the elementary school

students in the context of our study would complete the discussion about the relevance of pre-existing knowledge for students' success and learning within block and single class scheduling.

Finally, the present study relies on the Croatian national program for secondary education [26], which was mainly content-oriented and it likely imposed certain limitations to the present study (primarily regarding the aforementioned issues of learning topics and outcomes). However, the Croatian education system is currently undergoing a comprehensive curricular reform. Whereas the old Croatian national program for secondary education [32] was content based and focused on facts memorization, the new curriculum [65] emphasizes conceptual approach, reasoning-focused learning and problem-solving skills. As within many other European countries, the new Croatian curriculum is tailored towards emphasizing a scientific approach in teaching [5]. Thus, the new curriculum framework could be a basis for future comparative studies that might alleviate the limitations of the present study.

## 5. Conclusions

When evaluating the effects of block scheduling on students' success in learning and conceptual understanding, it is necessary to simultaneously consider the students' age, overall performance, pre-existing knowledge as well as the character of the learning topics, concepts and learning outcomes expected to be mastered, achieved and built into the pre-existing knowledge, respectively. In Croatian educational system, which is currently undergoing the process of new curriculum implementation across all levels of primary and secondary school education, it is recommended that block scheduling should be implemented in biology and other science-related subjects. The present research indicates that block scheduling should be implemented with caution as it could cause certain learning problems among low-performing students, particularly at the introductory levels of science subjects such as biology. However, it can likely improve the performance of medium-performing students, whereas good and excellent students seem to be successful regardless of the way being taught. In addition, it is important to emphasize that block-scheduled teaching should not be considered only as an extended teaching time. It also demands adequate teacher's guidance through well-planned timed activities that allow meaningful construction of concepts during the block. Based on our findings, we can further conclude that depending on the students' age, grade, and learning topics and outcomes, it would be good to combine benefits of single and block scheduling, and employ the hybrid block schedule that combines aspects of both traditional and block schedules, respectively. The results of the present study can contribute to efficient planning of science-related lessons at high school levels, especially if potentially negative effects of students' age, prior knowledge and overall performance on the students' learning success are aimed to be avoided.

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