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Block scheduled versus traditional biology teaching—an educational experiment using the water lily

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Abstract In this study, we compared a traditional teaching sequence (four distinct lessons) with a block schedule dealing with the ecological adaptations of the water lily. The educational unit contained original plant material and both experimental groups received the same tasks and working sheets. Pupils worked together in groups of three to four pupils in a self-regulated manner, carrying out hands-on experiments. However, both groups differed in their time schedule (four distinct lessons of 45 min versus one block of 180 min). Pupils from the traditionally scheduled education performed significantly better in the immediate post-test while these differences merged in retention.

Keywords Achievement · Biology teaching · Block scheduling · Gender · Weekly lessons · Water lily

Introduction

During the last decade of the previous century, biological education has shifted towards science education in the federal State of Baden-Wuerttemberg (SW Germany). Nowadays, methodological skills and experiments are highly emphasised in the new curriculum. Pupils are engaged in a variety of hands-on, student-centred and self-determined learning schedules and are obliged to present their results either in the classroom, for example by a poster demonstration or an oral presentation or even within the public of the school. Within this new curriculum, lab-work tasks have received a special importance. The effectiveness

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of lab-work tasks seems rather convincing (Fraser et al. 1987; Stohr-Hunt 1996; Thair and Treagust 1997; von Secker and Lissitz 1999), however, some cautionary comments have been provided, e.g. by Roth et al. (1997). Also, student-centred approaches are now favoured and teachers' activities are reduced which also promises more effective learning (see, e.g. Johnson and Lawson 1998; Lord 1998; Musheno and Lawson 1999; von Secker and Lissitz 1999). Usually, lab-work tasks and student-centred learning in groups are combined, and most of these approaches are based within the framework of self-determination theory (Deci and Ryan 1990) because pupils prefer to autonomously explore new fields of knowledge, to experience a high level of competence and to be socially related within a group of peers. All these approaches could be easily incorporated into a 'modern' approach of science education.

However, typical school settings often devote only one or two lesson per week (each lesson is 45 min long) to many subjects, and practitioners and teachers claim that larger blocks of time should be allocated to teach a topic it in its depth (Nichols 2005), e.g. to focus on one topic where innovating teaching practices, e.g. lab-work or collaborative peer-based learning could take place (Marchant and Paulson 2001; Nichols 2005). Further, such block schedules avoid instructional fragmentation and may allow a more flexible teaching and perhaps a more qualitative emphasis on high-level information processing (Salvaterra and Adam 1995; Nichols 2005). These ideas have also been incorporated into the new curriculum. However, arguments in favour of such block scheduled teaching are mostly verbal—at least in science education—rather than empirically tested while self-determined approaches, lab-work or group-based learning has deserved a wealth of research.

Education is often accused of jumping on bandwagons and of implementing changes without fully exploring the impact and effectiveness of such changes (Marchant and Paulson 2001). Nevertheless, the arguments in favour of block scheduled instruction seem reasonable and pupils might benefit from focusing on one specific subject which can now be examined in-depth and without any larger interruption. Recent studies, however, revealed contrasting results. Some authors found support for block scheduling which resulted in higher achievement (Carroll 1994; Kahzzaka 1997; Deuel 1999; Knight and DeLeon 1999; Lewis et al. 2003), and others not (Bateson 1990; Lockwood 1995; Lawrence and MacPherson 2000; Nichols 2005). This seems the case particularly in subjects that might require some repeated instruction, like maths or science (Marchant and Paulson 2001). Nichols (2005) suggests that despite researchers' best efforts, the multitude of variables that affect student achievement varies so greatly that it becomes difficult to control these factors. This is especially the case in large survey studies. Lewis et al. (2003) wrote in a cautionary manner that most of these studies that looked at achievement differences were at best causal-comparative in design, and in some cases purely correlational. Therefore, it seems worthwhile, to carry out didactical field experiments to investigate this question further, and, it might be helpful to use a controlled experiment where prior knowledge was assessed and the content of the lessons was under a strict control.

With regard to motivational variables, Schaal and Randler (2004) reported higher interest, competence and effort compared to traditional weekly courses and Knight and DeLeon (1999) reported that students in block schedule classes perceived that they used better study habits, were more engaged and interested in class activities, learned more and received more personal attention from the teacher.

The purpose of this study was to investigate whether a teaching sequence based on the ecological adaptations of the water lily (embedded into a larger sequence of ecological education) is more effective in terms of achievement when it is treated within one large time block covering an entire school morning (180 min) or whether it is better tied down into smaller bits which are taught always within one lesson (45 min) once during four weeks. To test this hypothesis, we applied a field experimental study in biology teaching where we employed the similar plant materials and the same working sheets in different classes so that the variable in question—block scheduled versus weekly courses—is the one that was treated differently. In this experimental approach we statistically control for prior knowledge and we keep the content of the lesson under control.

Methods

About 116 pupils (7th graders) participated in all three tests: 66 pupils from the block schedule and 50 from the weekly lessons. 53.4% ($N = 62$) were girls.

Educational program

The educational program was part of a larger unit which was pre-tested in the school year 2001/2002 (Gläser-Zikuda et al. 2005). Afterwards, the difficulties and problems of the respective parts concerning the water lily have been refined and detailed to better fit the needs of the new syllabus (Randler 2005). The teaching sequence presented here was carried out at the end of the school year 2004/2005. The educational treatment of the water lily was embedded into an entire teaching sequence that first started with a teacher-centred introduction into the ecosystem lake as a whole, and ended with some paperwork dealing with competition of different bird species and their ecological niche. In detail, the program dealt with the ecological adaptations of the water lily, e.g. the flexibility of the stalk, the aerenchym, which makes a gas transport possible, the wax like structure of the epidermis of the leaves. The entire educational unit consisted of four lessons each scheduled 45 min and the time devoted to the water lily made up 90 min. Both educational approaches comprised a set of experiments and of original material. Before encountering the plant material, pupils received a motivating task as introduction. They were confronted with the needs (ecological requirements) of a hypothetical plant which is adapted to living in a freshwater lake environment and they were asked to construct such a hypothetical plant species using some material which was presented in the classroom while working in groups. Afterwards, the pupils had to present their solutions to their classmates. Then, the hands-on and student-centred learning took place where pupils organised themselves in small groups of three to four which is considered an optimal group size (Lou et al. 1996). Original parts of water lilies were now under investigation and pupils compared different adaptations of this species with a typical plant that lives on land. Using original objects in biology classrooms is an essential tool because original objects or living animals present a highly motivating learning environment (Sherwood et al. 1989; Morgan 1992; Randler and Bogner 2002, 2006; Shepardson 2002). For example, handling of live versus exoskeletons of horseshoe crabs yielded similar results with regard to learning and retention while changes in attitude prevailed only when pupils handled live animals (Sherwood et al. 1989). Randler and Bogner (2002, 2006) further emphasised that models and taxidermic skins of bird species also provide motivating learning objects, while Morgan (1992) showed that the level of involvement may decrease learning and retention but increase interest and motivation. Morgan (1992) used snake models and living snakes and allowed some pupils to touch the snakes. In amphibian identification, models made of plastic were useful because pupils were allowed to touch them and this kind of "touch-and-feel" instruction seems to influence learning (Randler 2006). However, encountering additionally living animals again influenced learning and retention in a positive manner (Randler et al. 2005). We therefore decided to use original plant material for our teaching sequence. We therefore believe that these results concerning animals could be transferred to botany.

The only difference existed in the form of the treatments: (i) the block scheduled course was taught during one morning from 8.00 until 12:00, while (ii) the weekly lessons were enrolled single in lessons and always one lesson was devoted to the subjects.

Design and testing procedure

Prior knowledge was assessed by using a specific pre-test with good statistical properties (Randler and Bogner 2004). The test contained questions about ecology, ecological adaptations and the ecological niche concept. Immediately after the educational treatment a post-test was applied to assess learning effects. After a delay of seven weeks a retention test was applied. Retention test and post-test were equivalent. Pupils never were aware of any further testing and these tests were not used for grading purpose to avoid the influence of extrinsic variables.

Statistics

Data were normally distributed and parametric tests could be applied. We used a multivariate general linear model (GLM) using SPSS 13.0 to investigate the results in toto, followed by two general linear mixed models to look at post-test and retention test separately. These linear models compared main effects found by the multivariate procedure using Bonferroni adjustment. Effect sizes (Cohen's *d*) were calculated based on the original data and on the covariate adjusted means using MetaWin Calculator® (Sinauer Associates, Sunderland, MA, USA). All tests were carried out two-tailed.

Results

Significant differences between both treatment groups existed already prior to teaching and remained obvious throughout post-test and retention test. To account for these differences in prior knowledge, we applied a multivariate general linear model, using prior knowledge as covariate, and gender and treatment as fixed factors. In the initial model, the interaction between gender and treatment was not significant ($P > 0.4$; see Table 1). We found a significant influence of prior knowledge on post-test and retention, as expected. Further, there was a general influence of treatment strategy which was a result of the higher achievement scores of the pupils enrolled in weekly courses. This effect was found only in the post-test (Tables 2 and 3), while in retention, both groups scored similar. Gender also produced a significant result with girls performing better in post-test and retention and during both treatments. As there was no interaction effect, both girls and boys of the weekly course performed better in the post-test. Effect sizes (Cohen's *d*) showed a moderate effect of schedule immediately after the educational unit which merged to a small effect size in retention (Table 3). Differences between boys and girls were marginal in the

Table 1 Multivariate general linear model (GLM)

Wilks-Lambda	*F*	*df*	*P*	Partial η^2	
Constant	0.503	54.291	110	<0.001	0.497
Pre-test	0.899	6.209	110	0.003	0.101
Schedule	0.883	7.316	110	0.001	0.117
Gender	0.904	5.819	110	0.004	0.096
Gender * schedule	0.985	0.854	110	0.429	0.015

Schedule and gender were factors, pre-test was used as covariate and post-test and retention as dependent variable

Table 2 General linear mixed models using gender and treatment as fixed factors and pre-test as covariate

Source	Post-test model A		Retention model B	
	F	*P*	*F*	*P*
Constant	102.804	.000	50.272	.000
Pre-test	10.923	.001	7.187	.008
Gender	9.473	.003	7.752	.006
Instruction	13.710	.000	.718	.399
Gender * instruction	.057	.811	1.563	.214

Model A uses post-test as dependent variable and model B retention test

pre-test and more pronounced in the immediate post-test and in retention (Table 3), again, suggesting that girls gain a higher knowledge during biology education than boys.

Discussion

As both educational treatments incorporated the same original material, identical working sheets and similar experimental methods (student-centred learning in small groups) the observed differences in the immediate post-test seem to be a result of the differences in the enrolment of the courses. Weekly courses seem better compared to block scheduled courses, but this effect failed significance in the retention test. Usually, retention is considered the more serious test because it shows which knowledge is retained or stable over longer time periods. However, as there were no significant differences in retention, we feel that both educational approaches are suitable to teach ecological adaptations. Moreover, we think these results could be generalised in terms of educational strategies and teaching methods. Nevertheless, our approach also shows that block scheduled teaching is not superior to other forms. Other studies also revealed contrasting findings. Lawrence and McPherson (2000) used standardised achievement test but did not control for the content of the lessons. These authors found a superiority of traditional teaching over a block scheduled environment. Better performance in traditional courses was also found by Terrazas et al. (2003). Carroll (1994), Khazzaka (1997), Deuel (1999) and Knight and DeLeon (1999) used classroom grades rather than standardised test and revealed a higher score in block scheduled pupils. Similar results, especially in the social sciences were

Table 3 Descriptive statistics

Unadjusted means	*M*	*N*	SE	STD	Mean difference	*df*	*T*	*P*	Effect size
Pre-test									
Block schedule	4.79	66	.26	2.10	−1.45	114	−4.03	<.001	0.76
Traditional	6.24	50	.23	1.63					
Boys	5.13	54	.28	2.11	−.53	114	−1.40	.163	0.26
Girls	5.66	62	.25	1.96					
Post-test									
Block schedule	8.14	66	.33	2.70	−2.36	114	−4.76	<.001	0.90
Traditional	10.50	50	.36	2.57					
Boys	8.31	54	.35	2.61	−1.57	114	−3.02	.003	0.56
Girls	9.89	62	.37	2.93					
Retention									
Block schedule	7.08	66	.31	2.56	−.994	114	−1.83	0.070	0.34
Traditional	8.07	50	.46	3.28					
Boys	6.69	54	.37	2.74	−1.53	114	−2.90	.004	0.54
Girls	8.22	62	.36	2.90					
Covariate adjusted means	*M*	*N*	SE	STD	Difference of means	*df*	*P*	*F*	Effect Size
Post-test									
Block schedule	8.32	66	.31	2.51	−1.81	111	<.001	13.71	0.70
Traditional	10.14	50	.35	2.47					
Boys	8.52	54	.33	2.42	−1.42	111	.003	9.47	0.58
Girls	9.94	62	.31	2.44					
Retention									
Block schedule	7.26		.34	2.76	−.465	111	.399	.718	0.16
Traditional	7.73		.40	2.82					
Boys	6.77	54	.37	2.71	−1.44	111	.006	7.75	0.52
Girls	8.21	62	.35	2.75					

In the first part of the table, unadjusted means are given. The second part of the table presents estimated marginal means (covariate adjusted means). Pairwise comparisons are based on post-hoc comparisons adjusted for multiple comparisons (Bonferroni-correction). *F* is used for testing the effects of the factors based on the pairwise comparisons of the estimated marginal means. Effect size is presented as Cohen's *d*

found by Queen et al. (1997, 1998). Nichols (2005) applied a pre-/post-design during the process of conversion from traditional to block schedules but found little evidence to support the hypothesis that conversion to block scheduled formats would significant affect students' achievement. Lewis et al. (2003) criticise the inconsistency of the literature dealing with achievement differences, but they concluded that, consistently, block scheduling was not worse compared to traditional instruction. Our results do comply with these findings but we applied an educational treatment rather than an investigation of entire schools. Our approach benefits from controlling for prior knowledge via a standardised test and from controlling for the content of the lesson.

Further, organisational changes of schooling should also be accompanied by a behavioural change of the respective teachers. Adams and Salvaterra (1998) found that such organisational changes were often limited because individual teachers did not change their behaviour and adapted their teaching to the block schedule. Often, teachers do not provide appropriate instructional activities for the longer format, relying on presentation modes followed by extensive seatwork (O'Neill 1995; Knight and DeLeon 1999; Queen 2000). Rinkard and Banville (2005), however, found that sixty six percent of teachers perceived that students learned more in blocked versus traditional classes but they had no documented evidence. Another problem might be that too much time is wasted with activities other than instruction because the large time block is perceived as a large amount of time which may make teaching less effective (Rinkard and Banville 2005). Also, discussing students' perspectives is useful when considering the implementation of block schedules. Students reported many more advantages than disadvantages when comparing block schedules with traditional teaching, however, they had a slight preference for traditional scheduling (Slate and Jones 2000).

In pre-service teacher students, Schaal and Randler (2004) found that students of a block scheduled course (botany and plant identification) showed higher scores with regard to the motivational scales interest/enjoyment, perceived competence and effort/importance, while students of the traditional weekly course showed higher values in the perceived choice. Cognitive achievement did not differ significantly.

Apart from this main finding, gender differences also deserve some attention. Generally, as there was no interaction between gender and treatment, we discuss here the differences between boys and girls on a more general scale. While boys often perform better in physics and chemistry, girls usually score higher in biology (Weinburgh 1995; Lee and Burkam 1996), and, generally in achievement. Attempts have been made to plan physics education in a more girl-centred manner or even to divide classes according to gender (Hoffmann and Lehrke 1986). This often leads to better scoring in girls.

Educational implications

In contrast to many views of (theoretical) didactical approaches and practitioners, the block scheduled unit did not reveal superior effects in terms of retention. Nevertheless, we believe that such teaching methods should be used in school and discuss two aspects: First, pupils were indeed able to work at one specific topic during an uninterrupted time span. This means that such approaches should only be used when the topic is standing on its own during the entire time. Teaching different topics during such a block schedule does not seem to be useful. Second, it seems as pupils do cope with a regular change between different subjects or an instructional fragmentation as it is usually the norm in Germany, where subjects and teachers change every 45 min. Perhaps pupils are able to focus on every new subject—and often on the alternating persons—and perhaps this might be appreciated. Students reported that it is sometimes difficult to pay attention for such an extended period of time (Slate and Jones 2000; Marchant and Paulson 2001). Here, it would be a worthwhile task to do interviewing across a number of subjects. Further, different time blocks should also be tested. Perhaps there might be an optimal time span at which pupils benefit most. This could be the case in a double lesson covering a total of one and a half hour. This time span might be long enough to get in-depth views and to have ample time to focus on a specific topic, but, otherwise might not be to long to provoke boredom. Unfortunately, we did not measure these psychometric constructs (see, e.g. Gläser-Zikuda et al. 2005). It would be an interesting task to measure state-emotional variables such as boredom, interest, anxiety and well-being (see Gläser-Zikuda et al. 2005) or motivational variables, e.g. by using the Intrinsic Motivation Inventory (McAuley et al. 1987), during different time schedules. Further, hybrid types that change between short schedules and longer blocks within the same day may also be an interesting alternative to traditional schooling. At least, speaking with Lawrence and McPherson (2000) ''block scheduling does not meet all the desired outcomes'' (p. 182), and further research is needed to design better scheduling alternatives.

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